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Effects of Soil Moisture and Nitrogen Fertilizer on Pole Beans

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Contents

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INTRODUCTION

Snap beans rank first in value for vegetable crops in Oregon, with an annual gross value to growers in excess of 12 million dollars. The greater part of the production is of stringless Blue Lake pole beans, although there has been expansion in acreage of bush beans in recent years.

The major production area is in the Willamette Valley of western Oregon, where fertile soils and relatively long, cool summer days and cool nights provide conditions suitable for high yields and excellent quality of this product.

Timely and adequate irrigation is necessary for optimum yields because of sparse, infrequent summer rainfall. Average total rainfall for July and August is less than one inch for most of the Willamette Valley. Considerable variability occurs in rainfall in late spring and early summer. Appreciable rainfall may persist until late June in some years, while in other years the weather becomes quite dry after mid-April. It is this variation in natural rainfall that makes scheduling of irrigation an important consideration.

Objectives of this study were (1) to determine the effect of amount and frequency of irrigation and of nitrogen rates on yield and quality of stringless Blue Lake pole beans, and (2) to further study the usefulness of the electrical resistance method (gypsum stake unit) for estimation of soil moisture tension (suction) and for scheduling irrigations.

Research was conducted jointly by the departments of Horticulture, Soils, Agricultural Engineering, and Food Science and Technology. A preliminary field experiment, which included three moisture levels, was conducted at the Vegetable Research Farm near Corvallis in 1956. Work was continued in 1959 and 1960, when five moisture levels were used with variable nitrogen rates. In 1961, three moisture levels were used.

REVIEW OF LITERATURE

The literature on pole bean irrigation is limited. The greater portion of the work on irrigation of green snap beans has been related to the effects of supplemental irrigation on yields of bush beans. This will not be reviewed here. Irrigation of snap beans in the northeastern states has been recently reviewed by Vittum, *et al.* (*21*).[1] Research information is limited concerning areas where production of snap beans depends almost entirely upon irrigation and the primary problem is how often to schedule irrigations and what amounts of water to apply.

In western Washington, Allmendinger (*1*) studied the effects of irrigation on vegetable crops from 1945 to 1952. Total rainfall from April to September varied from 5.25 to 10.64 inches. By means of sprinkler irrigation, 12 to 16 inches of additional water were applied each year. The average yield of pole beans over the eight-year period was 8.9 tons per acre for irrigated plots and 4.1 tons for nonirrigated plots. Bullock (*6*), at the Southwestern Washington Experiment Station, near Vancouver, established an irrigation study on pole beans in 1955 in which irrigations were based on a frequency of one, two, and three weeks until harvest, with the frequency then modified to provide irrigation after every first, second, and third picks, respectively. The mean yields of Asgrow 231 pole beans in tons per acre for each of the frequencies were 9.0 for the three-week frequency, 10.4 for two weeks, and 13.3 for one week. The rate of application was approximately 2 inches per irrigation from planting to start of harvest and 2⅔ inches per irrigation during harvest.

Ware and Johnson (*22*) included pole and bush beans in an 11-year irrigation study of vegetable crops in Alabama. Yield response of beans to supplemental irrigation supplying one inch of water per week (when rainfall during the previous week had not supplied that amount) was compared to the yield of beans grown under natural rainfall. An average increase of 57% in yield of pole beans was obtained from irrigation without organic matter added to the soil, and an average increase of 41% from irrigation with organic matter added. No data on measurements of soil moisture were included.

Carreker and Cobb (*7*) and Land and Carreker (*13*) found that both quality and quantity of pole beans were improved with irrigation each year on bottomland and upland sites in Georgia. The average yield was 6,678 and 3,262 pounds per acre, with and without irrigation. Limited data included an average rate of evapotranspiration from pole beans of 0.19 inch per day.

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[1] Italic numbers in parentheses refer to Literature Cited, page 23.

Sprinkler irrigation costs and practices in the Willamette Valley, Oregon, were studied by Becker and Mumford (*3*). In 1946, 27 cases were studied; for pole beans, the average number of times irrigated was 9.5, total application averaged 18.5 inches, and amount per application was 1.95 inches. The cost of irrigating pole beans averaged $60.30 per acre per season. By conducting another survey of farms in the Willamette Valley in 1950, Becker (*2*) studied 31 cases of pole bean irrigation. The average number of irrigations was 9.6, with a total of 14.0 inches of water applied. Stippler (*19*) pointed out that no direct correlation existed between the quantity of water used and the yields obtained in a survey of pole beans and sweet corn in the Willamette Valley. The effects of soil type and certain production practices on yield appear to be important factors.

Tileston and Wolfe (*20*) estimated that average consumptive use of water for pole beans in the Willamette Valley was 18.4 inches, with a net irrigation requirement of 12.8 inches.

EXPERIMENTAL PROCEDURES

Experimental site

Experiments were conducted at the Oregon State University Vegetable Research Farm (east of Corvallis near the Willamette River) on Chehalis loam, a recent alluvial soil. Water-holding capacity of the soil averaged approximately 2.5 inches available water per foot of depth. In 1956, plots were located in an adjacent area near the site of sweet corn irrigation experiments previously described by Evans, *et al.* (*9*). In 1959, 1960, and 1961 plots were approximately 500 yards from the 1956 location in an area with the same soil type and similar topography.

Treatments and experimental design

1956. This preliminary experiment included three moisture treatments as main plots, with two spacings of plants within the row as subplots. Treatments were replicated three times. Each moisture plot was 50 x 35 feet and contained five rows of beans. Irrigation water was applied through overhead perforated pipes. Rows were spaced 5 feet apart, and a single-row plot, 25 feet long, was used as the basis for yield record.

Soil moisture treatments or irrigation levels were based on soil moisture tension values. Soil moisture was allowed to reach a prescribed tension at the 12-inch depth before irrigation water was applied. In some cases, however, tension values at the 6-inch depth were used for scheduling early irrigations. Prescribed tensions for the three moisture treatments, designated as M1, M2, and M3, are given in Table 1. Actual tensions achieved were somewhat different from those prescribed, and these are also shown in the table.

The two stand levels were achieved by thinning the plants at the first trifoliate leaf stage of growth to spacings within the row of two and three plants per foot.

No differential fertilizer treatments were used. All plots received approximately 80 pounds of nitrogen and 44 pounds of phosphorus per acre, banded 2 inches to the side and 2 inches below the seed at planting.

Table 1. PRESCRIBED TENSIONS AND TENSIONS ACHIEVED FOR THE 1956 SOIL MOISTURE TREATMENTS

Moisture treatment	Maximum tension called for at 12-inch depth	Maximum tension achieved at 12-inch depth
	bars	*bars*
M1	10.0	5.8
M2	2.0	2.2
M3	0.5	1.1

1959-1960. Five irrigation treatments with different rates of nitrogen as subplots were arranged in a randomized block design with four replications. In 1959, the five moisture treatments were designed to include a range of tensions from 0.6 to 4.2 bars, so that irrigation was scheduled when approximately 35 to 70% of the available moisture at the 12-inch depth had been depleted. The moisture treatments were modified slightly in 1960; the four moisture treatments (M1-M4) included the range in tension used for the five treatments in 1959 (0.6 to 4.2 bars) and a treatment was included in which plots were irrigated weekly until bloom, then every other day (M5). Prescribed tensions and those achieved are given in Table 2.

Irrigation plots were 27.5 x 25 feet—five rows spaced 5.5 feet apart. Plots were irrigated with a specially constructed plot irrigator (*16*) in 1959, 1960, and 1961. In 1959 the three center rows, each receiving a different rate of nitrogen fertilizer, were used for yield record. Fertilizer was banded at planting to supply approximately 50 pounds N, 65 pounds P, and 42 pounds K per acre. Additional nitrogen, as ammonium nitrate, was banded 6 inches to the side and 2 inches below the seed at planting, to appropriate plots, so that the three rates of nitrogen were 50, 100, and 200 pounds per acre. In 1960, each irrigation plot consisted of four rows for yield record with two rows

Table 2. PRESCRIBED TENSIONS AND TENSIONS ACHIEVED FOR THE 1959 AND 1960 MOISTURE TREATMENTS

Moisture treatment	Maximum tension called for at 12-inch depth		Maximum tension achieved at 12-inch depth	
	1959	1960	1959	1960
	bars	*bars*	*bars*	*bars*
M1	4.2	4.2	4.5	4.6
M2	2.6	2.4	3.7	2.7
M3	1.6	1.2	2.2	1.9
M4	1.0	0.6	2.4	1.0
M5	0.6	Calendar schedule*	0.9	0.4

* M5, 1960—irrigate weekly until bloom, then every other day.

(duplicates) of each nitrogen treatment. A uniform application of 50 pounds N, 65 pounds P, and 42 pounds K per acre was applied in a band 2 to 3 inches to the side and 2 inches below the seed at planting. The remaining nitrogen to supply 100 and 200 pounds per acre was sidedressed in a band 6 to 8 inches from the row two days after bean seedlings had emerged.

1961. Two of the three moisture treatments were on a calendar scheduling. The M5 treatment was irrigated weekly until bloom, then every other day, while the M6 treatment was irrigated every other day throughout the season. These were compared to a treatment (M4) in which it was intended that plots would be irrigated when the moisture tension reached 0.6 bars. The tension values accomplished for the M4 treatment were considerably higher than planned, as indicated in Table 3. Irrigation plots were split so that one-half of each plot (two rows) received an early irrigation one week after emergence as compared to the regular irrigation schedule. Two weeks after emergence, the M5 (weekly) and M6 (every other day) schedules of irrigation began. Treatments were in a randomized block design with four replications.

Fertilizer was band-placed at planting at approximately the same rate as in 1959 and 1960. At the same time, 50 pounds of nitrogen per acre was banded 6 to 8 inches to the side of the seed. No variable rates of nitrogen were used.

Irrigation scheduling and moisture measurement

Gypsum stake units (*9*) were used for measuring soil moisture tension and for scheduling irrigations. In 1956, two stake units per moisture plot were installed in the row so that readings were taken at

Table 3. PRESCRIBED TENSIONS AND TENSIONS ACHIEVED FOR THE 1961 SOIL MOISTURE TREATMENTS

Moisture treatment	Maximum tension called for at 12-inch depth	Maximum tension achieved at 12-inch depth
	bars	*bars*
M4	0.6	3.1
M5	Irrigate weekly until bloom, then every other day	0.7
M6	Irrigate every other day throughout	0.4

depths of 6, 12, 18, and 24 inches. In the M1 and M2 treatments, two additional stakes were installed, with readings being taken at 30, 36, 42, and 48 inches. Stakes had been previously calibrated in this soil, and the curve used is presented in Figure A, Appendix. In 1959, 1960, and 1961, two stake units per moisture plot were used, giving a total of eight stakes per moisture level.

The need for irrigation was based on average soil moisture tension at the 12-inch depth, except for some cases where the 6-inch depth was used for scheduling early irrigations. All replications were irrigated alike. Readings from the stake units were taken every three days or twice weekly. Soil moisture samples for checking stake unit readings were taken periodically and handled as described in a previous publication (*9*).

Water pressure at each lateral or at each plot irrigator was carefully maintained at a fixed value in order to apply a constant rate to each plot. Calculated amounts were checked against can-catchment data in order to evaluate the pattern of distribution and the amount of water applied.

Moisture extraction pattern—1956

The moisture extraction pattern for mature bean plants from one extra plot of the M2 moisture treatment was determined. Soil moisture was maintained in the M2 level as prescribed, but the soil was allowed to dry for two weeks near the end of the season prior to soil sampling. Soil samples were taken for a depth of 0-48 inches at 6-inch increments and at 6-inch intervals across the rows. The sampling was replicated three times, and the average percent moisture was converted to tension for presentation.

General cultural practices

Bean seed was planted mechanically and band placement of fertilizer was made as outlined earlier. Prime-Pak (Ferry-Morse FM-1) stringless Blue Lake pole beans were seeded in rows spaced 5.0 or 5.5 feet apart and were thinned to a stand of three plants per foot. In 1956, an additional stand level was included. Cultivation was employed as needed to control weeds, and insects were controlled according to general practice.

Dates of planting and of first pick during the four years were as follows: 1956 (May 8, July 23); 1959 (May 16, July 24); 1960 (June 3, August 8); and 1961 (May 27, August 2).

Yield and quality measurements

Each individual plot was harvested by hand at four- to five-day intervals according to the usual harvest procedure. All moisture treatments were on the same picking schedule, and the number of picks ranged from six to eight for each of the four years. Yield data were subjected to analysis of variance.

After weighing pods from individual plots, replicates of a given treatment were combined and sieve size grades of pods were determined on samples by use of a commercial grader in the Food Science and Technology pilot plant. Pods were separated into six sieve size grades— 1 and 2, 3, 4, 5, 6, and 7 and larger—and weights were taken. Generally, sieve size distribution data presented will be those of percentage by weight of sieve sizes 4 and smaller. In some cases, estimates were made of the number of malformed or crooked pods in a given sieve size from each of the moisture treatments.

In 1959 and 1960, sample pods of sieve sizes 3 and 5 were canned for quality evaluation; in 1961, pods of sieve sizes 3 and 6 were canned for evaluation. The beans were graded and snipped by commercial-size equipment. The individual sizes were cut to 1-inch lengths and blanched 1½ minutes at 175° F. After cooling in tap water, 303 x 406 cans were filled with 9 ounces net weight. A 70-grain salt tablet was added prior to completing the fill with boiling water and closing. Cans were processed for 20 minutes at 240° F, cooled, and stored until later analyses. Percentages of seed and fiber in pods of each of the sieve sizes were determined by the Food and Drug Administration method (*17*).

From each of the moisture treatments in 1959, a 2-pound sample of fresh sieve size 4 pods from the fourth pick was dried, ground, and analyzed for N, P, K, Ca, and Mg. Nitrogen was determined by the Kjeldahl method (*14*); phosphorus, colorimetrically by the molybdenum blue method of Fiske and Subbarow (*10*); K and Ca with the flame photometer (*5*); and Mg by the thiazole yellow procedure of Drosdoff and Nearpass (*8*).

RESULTS

Yields, sieve size grades, and moisture tensions

1956. Total number of irrigations, amount of water applied, rainfall, and soil moisture tensions for the three moisture treatments are shown in Table 4. Amounts of irrigation and rainfall by dates during 1956 are given in Figure B, Appendix.

Data on yield and sieve size distribution (Table 5) show that there was a significant difference in yields due to moisture treatments. There was no significant difference in yield between the M2 and M3 treatments, but M2 and M3 yields were significantly greater than yield at the M1 moisture level.

The percentage of pods sieve size 4 and smaller was greater for M2 and M3 moisture treatments than for M1 at the first picking, indicating some delay in maturity. The seasonal averages for sieve sizes 4 and smaller indicate a reversed trend. Yield was very low for the M1 treatment, and many of the bean pods, although of a small diameter, were short and poorly filled.

Table 4. Irrigations, Rainfall, and Soil Moisture Tensions for the 1956 Soil Moisture Treatments

Moisture treatment	Irrigations		Rainfall	Total water	Mean maximum tension at 12-inch depth
	Number	Amount			
		inches	*inches*	*inches*	*bars*
M1	0	0	3.3	3.3	5.8
M2	6	17.2	....	20.5	2.2
M3	11	18.4	....	21.7	1.1

Table 5. Effect of Moisture Treatments and Stand Levels on Yields and Sieve Size Grades of Pole Beans, 1956

Moisture treatment	Yield (tons/acre)			Sieve size grades size 4 and smaller	
	2 plants/ft.	3 plants/ft.	Mean	First pick	Season
	tons/A	*tons/A*	*tons/A*	*%*	*%*
M1	2.0	2.2	2.1	49	58
M2	6.8	7.2	7.0	54	50
M3	7.5	7.9	7.7	58	46

1959-1960. The number of irrigations ranged from three to eight for the five moisture treatments in 1959 and from 3 to 24 in 1960. Amount of irrigation ranged from 8.6 to 15.6 inches in 1959 and from 7.7 to 16.9 inches in 1960 for the respective moisture treatments (Table 6). Dates and amounts of irrigation and rainfall are shown in Figures B and C, Appendix.

Table 6. IRRIGATIONS, RAINFALL, TOTAL WATER, AND SOIL MOISTURE TENSIONS FOR 1959 AND 1960 SOIL MOISTURE TREATMENTS

Moisture treatments	Irrigations		Rainfall	Total water	Mean maximum tension at 12-inch depth
	number	*inches*	*inches*	*inches*	*bars*
1959					
M1	3	8.6	2.0	10.6	4.5
M2	6	14.4		16.4	3.7
M3	7	16.0		18.0	2.2
M4	7	13.6		15.6	2.4
M5	8	15.6		17.6	0.9
1960					
M1	3	7.7*	0.9	8.6	4.6
M2	4	10.7		11.6	2.7
M3	6	15.8		16.7	1.9
M4	7	15.5		16.4	1.0
M5	24	16.9		17.8	0.4

* Includes one-inch irrigation June 22 on all plots after nitrogen sidedress.

Yields of pole beans were significantly increased as amounts and frequency of irrigation were increased and as mean maximum tensions at the 12-inch depth were decreased. The yields in 1959 ranged from 6.0 to 9.8 tons per acre, representing averages for replications 3 and 4 only. Because of injury to plants from symphylans, yields for moisture treatments in replications 1 and 2 are not included. In 1960 the M1 moisture treatment yielded 8.3 tons per acre, and the M5 treatment yielded 9.5 tons. Yield of the M5 treatment, which received irrigation weekly until bloom and then every other day, was about the same as the yield of the M4 treatment, which received seven irrigations (Table 7).

No significant differences in yields were found because of nitrogen rates in 1959 (Table 8). In 1960, average yields from the 200-pound nitrogen rate per acre were significantly lower than the yield

Table 7. EFFECT OF MOISTURE TREATMENTS ON YIELDS AND SIEVE SIZE GRADES OF POLE BEANS, 1959 AND 1960

Moisture treatment	Yield		Sieve size grades—size 4 and smaller			
			First pick		Season	
	1959	1960	1959	1960	1959	1960
	tons	*tons*	%	%	%	%
M1	6.0	8.3	35	46	46	49
M2	7.4	8.9	36	53	47	47
M3	8.3	9.0	42	57	51	49
M4	9.0	9.4	40	44	49	45
M5	9.8	9.5	42	42	49	45

Table 8. EFFECTS OF MOISTURE TREATMENTS AND NITROGEN RATES ON YIELDS (TONS PER ACRE) OF POLE BEANS, 1959 AND 1960

Nitrogen rates	Moisture treatments					Nitrogen means
	M1	M2	M3	M4	M5	
1959						
N-50	6.1	7.2	8.3	8.7	10.1	8.1
N-100	5.8	7.3	8.5	8.8	9.3	7.9
N-200	6.2	7.8	8.1	9.5	9.9	8.3
Moisture treatment means	6.0	7.4	8.3	9.0	9.8	
1960						
N-100	8.6	9.0	8.7	9.6	10.0	9.2
N-200	8.1	8.7	9.4	9.2	9.0	8.9
Moisture treatment means	8.3	8.9	9.0	9.4	9.5	

LSD moisture treatment means:
1959 (.05) 2.8
(.01) NS
1960 (.05) 0.8
(.01) NS

LSD nitrogen means:
1959 (.05) NS
(.01) NS
1960 (.05) 0.2
(.01) NS

from the 100-pound nitrogen rate. There was a significant moisture x nitrogen interaction, in which the higher rate of nitrogen (200 pounds) depressed yields in all moisture treatments except M3, where yield was increased as compared to the 100-pound rate of nitrogen. No logical explanation is offered for this interaction.

Cumulative yields for the five moisture treatments in 1959 and 1960 are shown in Figures D and E, Appendix.

1961. Amounts of irrigation ranged from approximately 13 inches for the M4 moisture treatment to 26 inches for M6 (Table 9). Unfortunately, the desired tension was not achieved for M4 since it averaged considerably higher than the intended 0.6 bar level. Soil moisture tension values for M5 and M6 treatments were below 1.0 bar.

Table 10 shows that yields from the M5 and M6 moisture treatments were significantly higher than those from the M4 treatment. The apparent difference between plots receiving the early irrigation one week after emergence and plots receiving the regular schedule of irrigation was not statistically significant.

The percentage of pods sieve size 4 and smaller was higher for M6 than for M5 or M4; this was apparent both at the first pick and for the season. These results, although more pronounced than in earlier experiments, show that increased amount and frequency of irrigation delayed development or maturity of pods; or, conversely, the drier treatment accelerated maturity.

Table 9. IRRIGATIONS, RAINFALL, TOTAL WATER, AND SOIL MOISTURE TENSIONS FOR THE 1961 MOISTURE TREATMENTS

Moisture treatment	Irrigations*		Rainfall	Total water	Mean maximum tension at 12-inch depth
	number	*inches*	*inches*	*inches*	*bars*
M4	4	12.8	1.3	14.1	3.1
M5	25	22.5		23.8	0.7
M6	35	25.7		27.0	0.4

* Irrigations indicated are for regular schedule; early irrigation (two rows of each plot) included ½ inch just after emergence, in addition to amounts listed above.

Table 10. EFFECT OF MOISTURE TREATMENTS ON YIELDS AND SIEVE SIZE GRADES OF POLE BEANS, 1961

Moisture treatment	Yield			Sieve size grades size 4 and smaller	
	Early	Regular	Mean	First pick	Season
	tons	*tons*	*tons*	%	%
M4	9.3	9.2	9.2	21	36
M5	10.4	9.9	10.1	37	41
M6	10.6	10.6	10.6	50	45
LSD moisture treatment means:	(.05) 0.4				
	(.01) 0.6				

Yields, soil moisture tensions, and irrigations

The highest yields were associated with the lowest soil moisture tensions and they followed the same general pattern for each of the years, although yields differed for the four years studied. In Figure 1, soil moisture tensions are expressed as mean maximum tension at the 12-inch depth; in Figure 2, tensions are expressed as mean tension for the growing season. With very frequent irrigations (M6-1961), yield was increased; however, the assumption that a tension near zero will further increase yield cannot be made from existing data.

The relationship between the number of irrigations and the yield of pole beans is shown in Figure 3. Yields were increased as the number of irrigations were increased. However, the amount of water applied and the soil moisture tension values should be kept in mind when the relationship between the number of irrigations and the yield is considered, since amounts of water per irrigation and frequency of irrigation varied widely between treatments.

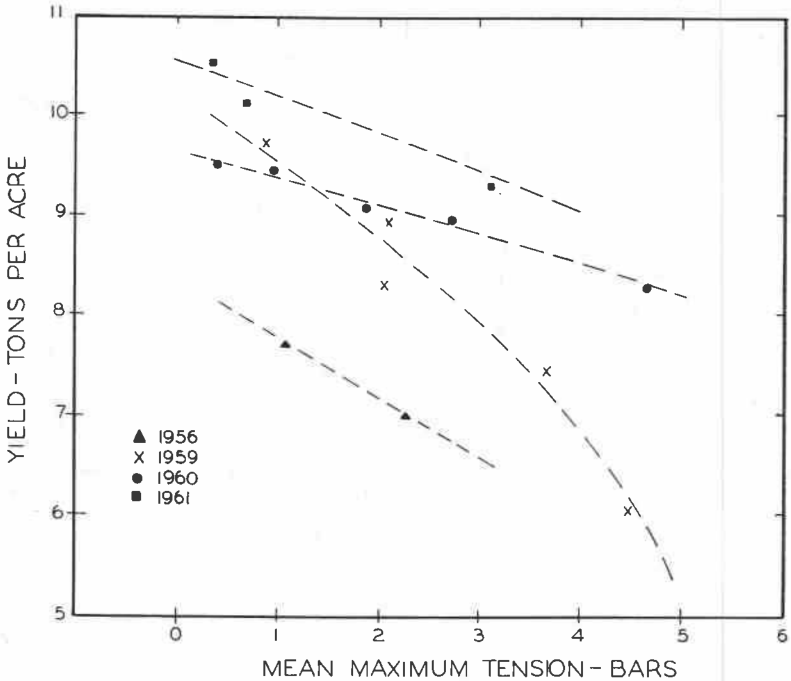

Figure 1. Relationship between mean maximum tension, 12-inch depth, and yields of pole beans.

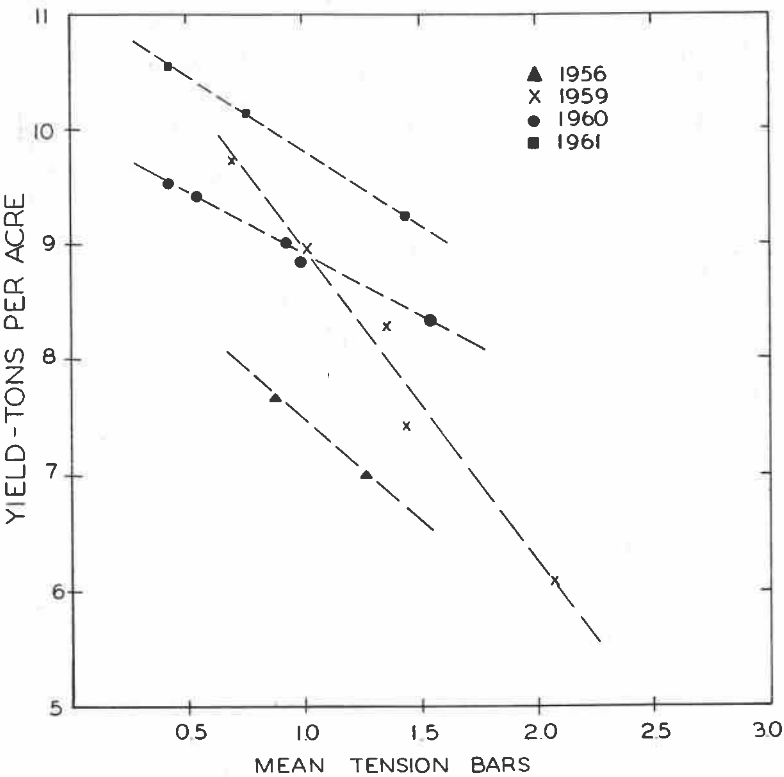

Figure 2. Relationship between mean tension (depth-season) and pole bean yields.

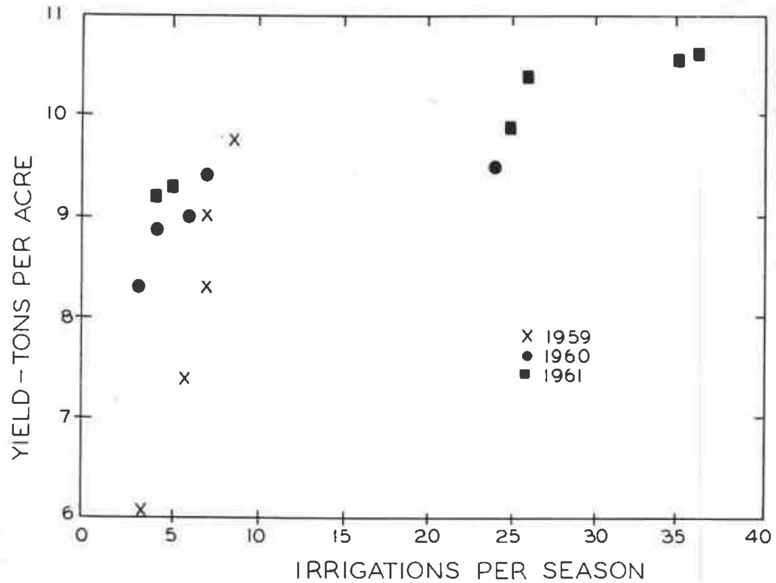

Figure 3. Relationship between number of irrigations per season and yields of pole beans.

Moisture extraction pattern—1956

Figure 4 shows the moisture extraction pattern for mature pole bean plants across two rows that ran east and west in the M2 moisture treatment. Percent moisture was converted to bars tension. The highest tensions ranged from the surface down to 12 to 18 inches, with the highest ones directly under the plants. From these data, there appeared to be root activity in moisture extraction down to depths of 30 inches or greater.

Quality and mineral composition of pods

In observations made during 1956 and 1959, the number of malformed or crooked pods appeared to be higher for the treatments receiving the least amount of irrigation. In 1960, a 4-pound sample of pods (2 pounds each of sieve sizes 3 and 5) was taken at each pick, and malformed pods were separated. Numbers of malformed pods per pick (4-pound sample) averaged 66, 53, 54, 43, and 35 for the M1 through M5 treatments, respectively, indicating a smaller number at the higher moisture levels.

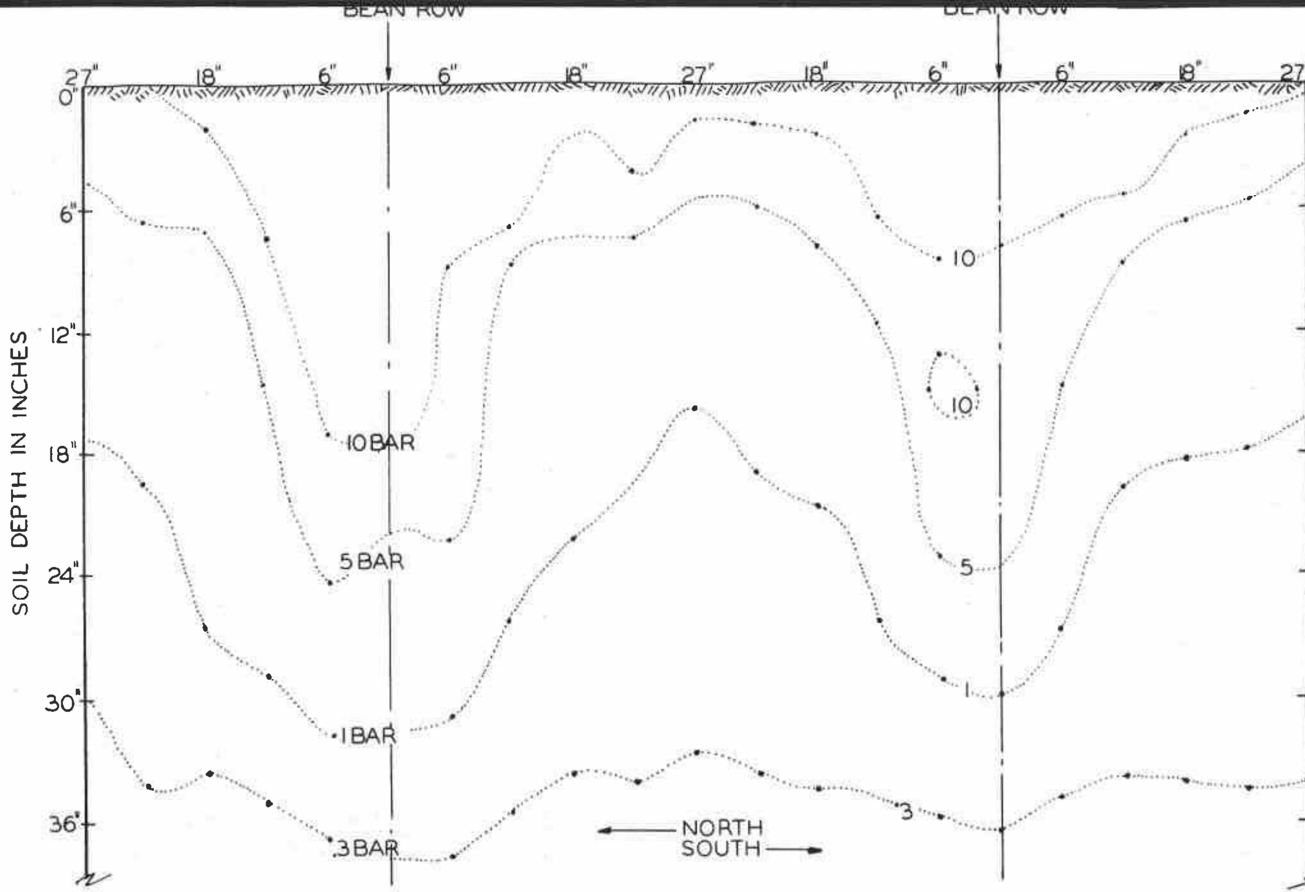

Figure 4. Moisture tension values at selected depths, M2 treatment, 1956.

The percent of seed and percent of fiber in canned pods were generally lowest in the higher moisture treatments, especially in 1959, as shown in Tables 11 and 12. Effects of moisture treatments and nitrogen rates on percent of seed and fiber of sieve size 5 pods are shown in Figures 5, 6, and 7. Fiber in pods was lowest at the highest moisture levels. In 1960, percent seed and percent fiber of sieve size 5 pods were lower at the fourth pick than at the first pick. Percent seed was not appreciably different at the five moisture levels in 1960. Effects of nitrogen rates on percent seed and percent fiber were not consistent, although there was some tendency for lower values at the higher rate of 200 pounds per acre.

Effects of moisture treatments and nitrogen rates on mineral composition of size 4 pods (fourth pick, 1959) are given in Table 13. Although differences were not great, there was a tendency for an increase in N, P, and K content as amount and frequency of irrigation was increased. Increasing rates of nitrogen caused an increase in nitrogen content of pods.

Table 11. Effect of Moisture Treatments on Percent Seed and Percent Fiber in Pole Bean Pods, Fourth Pick, 1959 and 1960

Moisture treatment	Percent seed				Percent fiber			
	1959		1960		1959		1960	
	Size 3	Size 5	Size 3	Size 5	Size 3	Size 5	Size 3	Size 5
	%	%	%	%	%	%	%	%
M1	6.38	6.58	2.08	2.78	.1847	.1621	.0087	.0198
M2	1.74	4.76	2.11	2.68	.0319	.1287	.0104	.0131
M3	2.06	3.26	2.33	2.94	.0327	.0487	.0100	.0162
M4	1.74	3.22	2.19	2.78	.0310	.0262	.0116	.0131
M5	1.55	3.15	2.26	2.84	.0267	.0362	.0053	.0137

Table 12. Effect of Moisture Treatments on Percent Seed and Percent Fiber in Pole Bean Pods, First Pick, 1961

Moisture treatment	Percent seed		Percent fiber	
	Size 3	Size 6	Size 3	Size 6
	%	%	%	%
M4	2.99	5.12	.0266	.0407
M5	3.18	4.76	.0134	.0358
M6	3.30	4.62	.0178	.0298

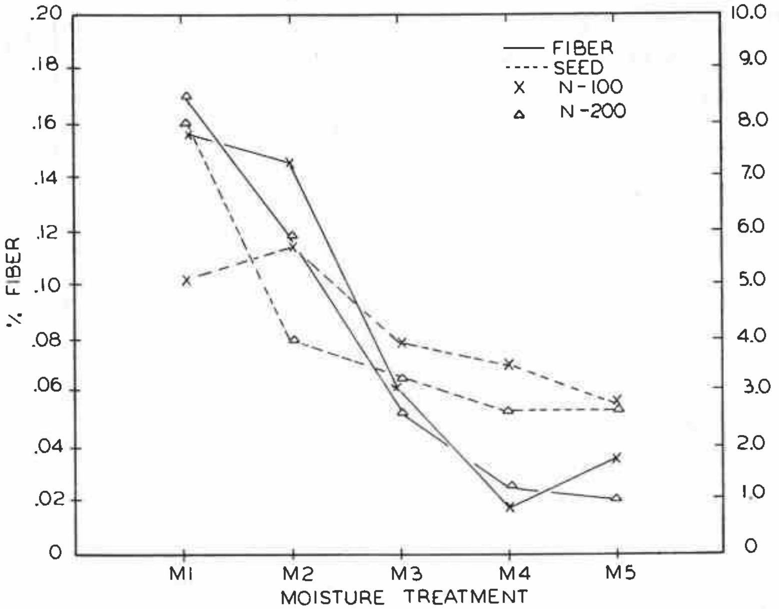

Figure 5. Effect of moisture treatments and nitrogen rates on percent seed and percent fiber of sieve size 5 pods, fourth pick, 1959.

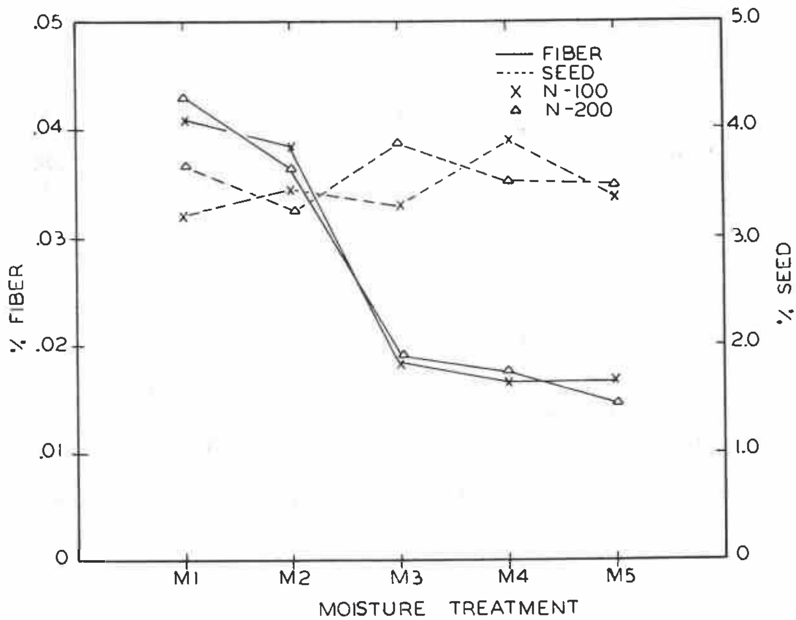

Figure 6. Effect of moisture treatments and nitrogen rates on percent seed and percent fiber of sieve size 5 pods, first pick, 1960.

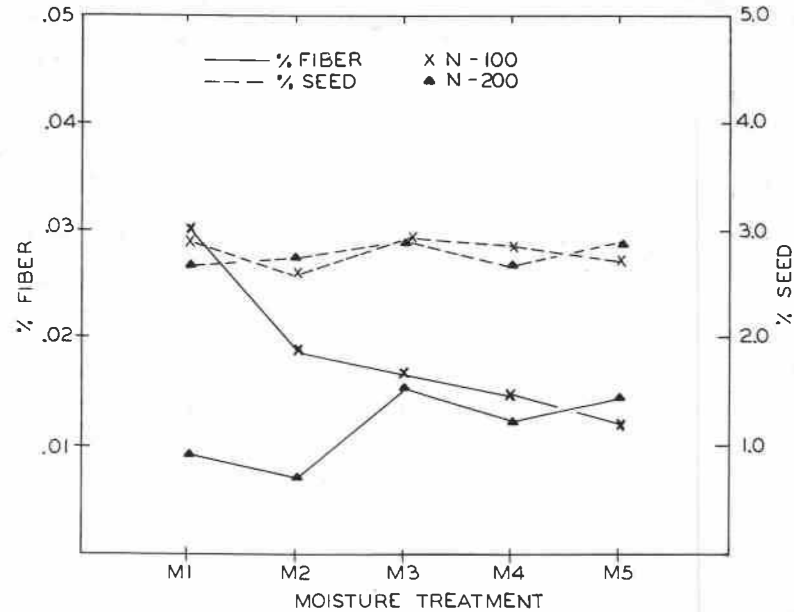

Figure 7. Effect of moisture treatments and nitrogen rates on percent seed and percent fiber of sieve size 5 pods, fourth pick, 1960.

Table 13. Effect of Moisture Treatments and Nitrogen Rates on Mineral Composition of Size 4 Pods, Fourth Pick, 1959

Treatment	Percent dry weight basis				
	N	P	K	Ca	Mg
	%	%	%	%	%
M1	3.69	.46	2.33	.29	.31
M2	3.78	.46	2.27	.28	.33
M3	3.77	.50	2.29	.27	.32
M4	3.84	.50	2.65	.27	.31
M5	3.96	.48	2.87	.27	.33
Rates					
N-50	3.79	.49	2.46	.28	.31
N-100	3.79	.48	2.54	.28	.32
N-200	3.85	.47	2.44	.27	.32

DISCUSSION

A consistent trend indicating that yields of pole beans increased as soil moisture tension decreased was evident in all of the experiments. This trend was apparent, although yields varied from year to year, with yields being highest in 1961 and lowest in 1956. Highest-yielding moisture treatments were those in which the seasonal mean maximum tension at the 12-inch depth averaged 1.0 bar or less. Thus, it would appear that on this Chehalis loam soil, available moisture at the 12-inch depth should not be allowed to drop below 55 to 65% for production of highest yields.

Since yields were increased as soil moisture tension decreased, treatments in 1960 and 1961 included scheduling of quite frequent irrigations. In 1960, no significant difference in yield was found between the M4 treatment (mean maximum tension of 1.0 bar), which received seven irrigations supplying 15.5 inches of water, and the M5 treatment (mean maximum tension of 0.4 bar), which received 24 irrigations supplying 16.9 inches of water; M5 was irrigated weekly until bloom, then every other day. The M4 treatment received four irrigations in 1961, while a comparable treatment in 1960 and 1961 received seven and eight irrigations, respectively. It could be assumed that differences in yield may not have been as great between M4 and M5 moisture treatments in 1961, had the M4 treatment received seven or eight irrigations instead of only four. It is unfortunate that the soil moisture tension values were so high for M4 in 1961. Further work would be needed for a more concise evaluation on the effects of frequent scheduling of irrigation (every day or every other day) on yield of pole beans.

How much lowering of air or soil temperatures was accomplished as the frequency of irrigation was increased was not studied, although a limited number of observations of air temperature were made near the end of the season in 1961. These observations, on three dates, indicated that mid-afternoon air temperatures in the M5 and M6 plots were 1 to 3° F lower than those in the M4 plots. With bush beans in Arkansas, Bowers *et al.* (*4*) found that daily irrigations increased the pod set of the late planting when air temperatures were exceptionally high, 100° F or above. Air temperatures 6 inches above the ground were significantly lower with this irrigation treatment, and the increased pod set made the difference between a light crop and no crop at all. Janes and Drinkwater (*12*) also suggested that temperature changes resulting from irrigation were beneficial. In the present study, effects of moisture treatments on pod set were not evaluated, although yield data were obtained.

Not only were yields increased as the amounts and frequency of irrigation were increased, but there tended to be an increase in percentage of sieve size 4 pods and smaller, as compared to the drier treatments. Thus, there was some delay in maturation rate, which also suggests that temperatures may have been lower in plots receiving more frequent irrigations.

Usually the percent of fiber and sometimes the percent of seed in a given size of canned pods were lowest in treatments which received the highest total amounts of water and/or the most frequent irrigation. This was especially apparent in 1959 when differences in yield were large between moisture treatments. Limited data also indicate fewer crooked pods at the higher moisture levels. Reynolds and Rogers (*15*) in Maryland reported that the beneficial effects of irrigation on quality of snap beans were no less important than effects on yields, since irrigation generally decreased the percentage of severely crooked pods and lowered the seed and fiber content as compared to nonirrigated check plots. Gabelman and Williams (*11*) concluded the following from bush bean irrigation studies in the central sand area of Wisconsin: "Although irrigation does not materially alter rate of fiber development, it has proved to be an extremely powerful tool for production of high yields, with mechanical harvesting, of good quality, low fiber content beans, because of the way in which it influences concentration of flower set and degree of pod retention." Sistrunk, *et al.* (*18*) found that chemical and physical differences in fresh and canned beans were affected by irrigation.

No significant increase in yield was obtained from nitrogen rates higher than 100 pounds per acre. This is in agreement with other studies at this station, where nitrogen rates were varied and irrigation maintained at an adequate level.

SUMMARY AND CONCLUSIONS

Experiments involving soil moisture (irrigation) treatments were conducted on stringless Blue Lake pole beans during 1956, 1959, 1960, and 1961 on Chehalis loam soil near Corvallis. Nitrogen rates were included in 1959 and 1960.

Highest yields were related to treatments in which mean maximum soil moisture tensions at the 12-inch depth averaged 1.0 bar or less. Moisture levels ranged from 0.4 to 5.8 bars maximum tension at the 12-inch depth. Thus, highest yields were obtained under the highest moisture levels used; that is, when approximately 16 to 18 inches of irrigation water was applied in seven to eight or more irrigations. Although yields were high from treatments frequently irrigated—weekly until bloom, then every other day—in 1960 and 1961, results were not conclusive; further work is needed for a more concise evaluation of frequent irrigation as compared to treatments irrigated every 7 to 10 days.

Fiber in canned pods was lowest in the highest moisture treatments, and there were fewer crooked or malformed pods at higher moisture levels. Percent seed of pods was not consistently influenced by moisture treatments.

Differences in yields from nitrogen rates were not great. A rate of 100 pounds nitrogen per acre appeared to be optimum.

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APPENDIX

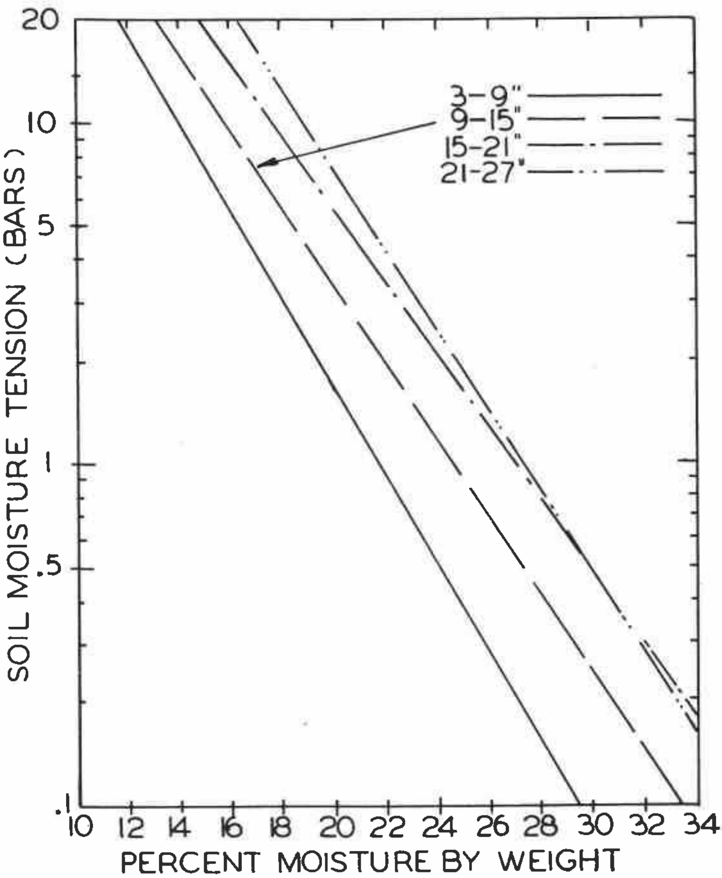

Figure A. Moisture-tension curves for four depths of the soil at the experimental site.

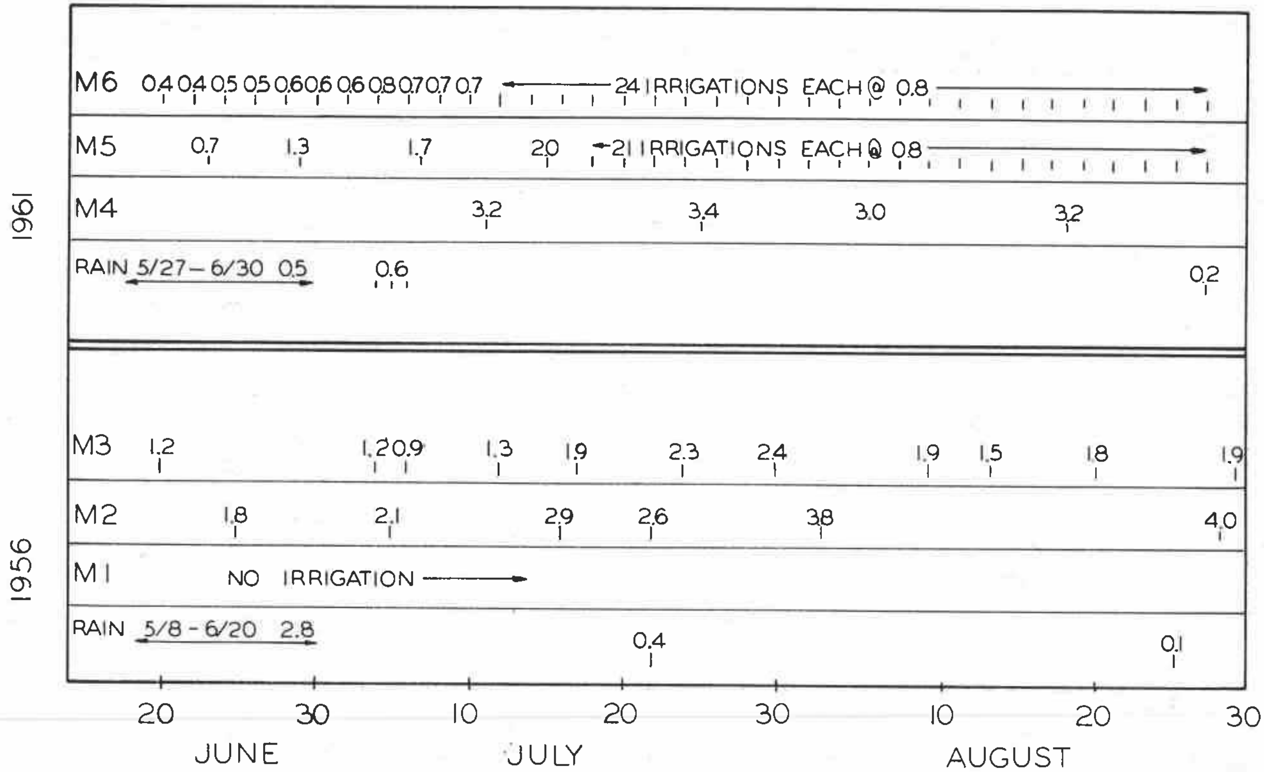

Figure B. Frequency and amount of irrigation and rainfall for moisture treatments during 1956 and 1961.

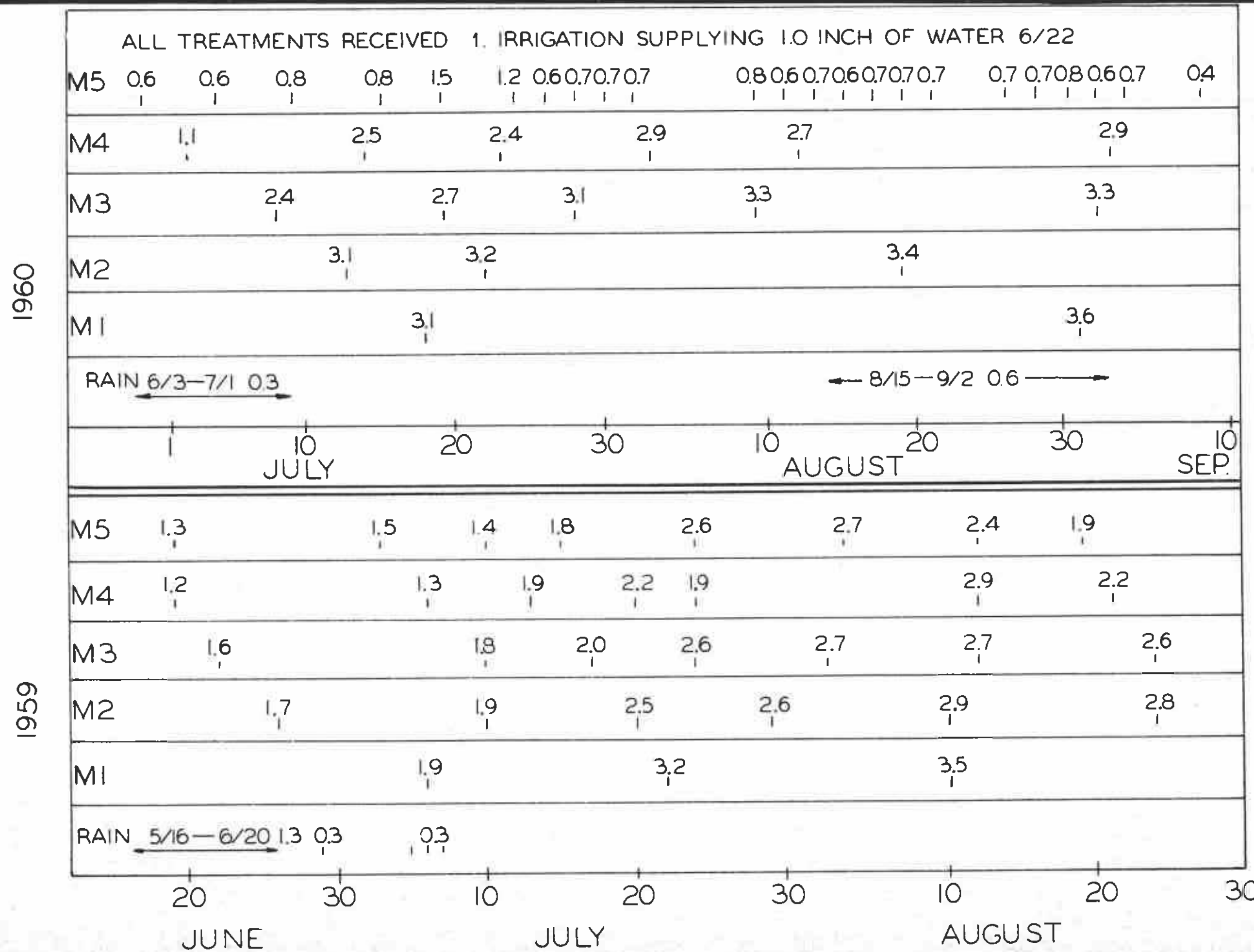

Figure C. Frequency and amount of irrigation and rainfall for moisture treatments during 1959 and 1960.

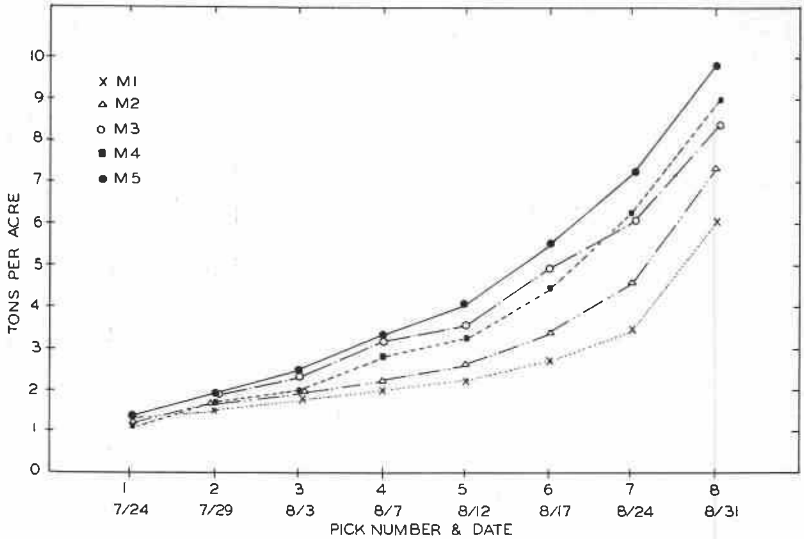

Figure D. Cumulative yield of pole beans, 1959.

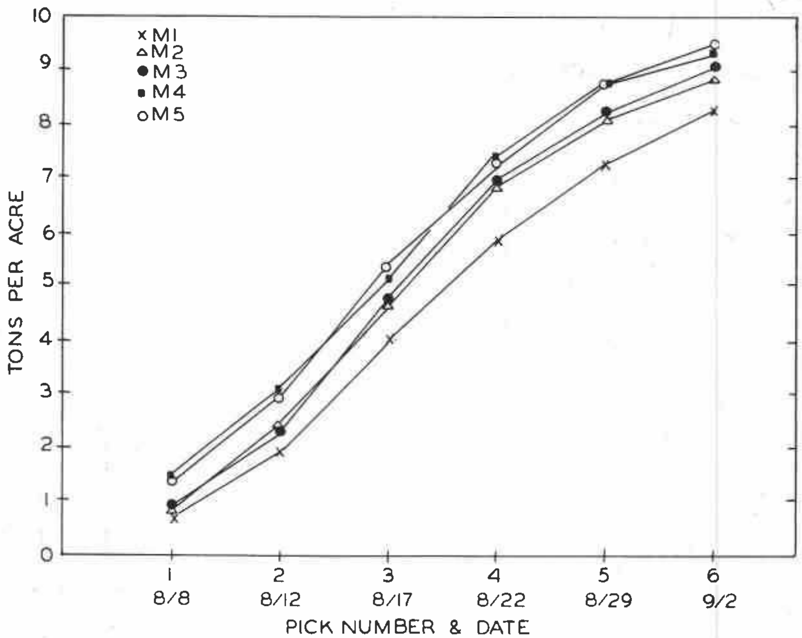

Figure E. Cumulative yield of pole beans, 1960.