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Response of Snap Bean to Irrigation, Nitrogen Fertilization, and Plant Population[1]

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Abstract. **Snap bean, *Phaseolus vulgaris* L., yield was increased by higher plant population, more frequent irrigation, and additional N applied as a topdress. Highest yields were obtained with the irrigation-fertilization program that included applications of 8 mm of water at 23 mm of pan evaporation until 1/3 foliage cover, at 15 mm of pan evaporation until 2/3 foliage cover, then at 8 mm of pan evaporation until harvest with N applications to maintain petiole NO_3-N level above 1500 ppm preblossom and 1000 ppm during fruit development. Response of 30 x 8 cm and 91 x 3 cm plant spacings to irrigation and N fertilization were similar.**

Pan evaporation data can be used to schedule irrigation under varied climatic conditions and maintain a low soil water tension throughout snap bean growth. The relationship of water use by snap bean to pan evaporation changes with crop development. An adjustment must be made to compensate for the changing relationship; and frequent irrigation and N fertilization must be made to snap beans produced on sandy soil under humid conditions.

Snap bean, *Phaseolus vulgaris* L., has a relatively shallow water-extracting root system (7) and is responsive to frequent irrigations (2, 3, 6, 10, 11, 14). Maximum yields have been obtained when low soil water tension was maintained throughout snap bean growth (10, 14). Water stress during flowering results in the greatest yield reduction (2, 3, 6). Kattan and Fleming (6) reported that preblossom drought did not reduce yields, however, Gabelman (3) and Dubetz and Mahalle (2) obtained large yield reductions from preblossom water stress. Water stress during fruit development reduced both yield and pod quality (3, 6).

Several methods have been proposed for scheduling snap bean irrigation. Nettles (12) utilized evaporation from an open pan to schedule irrigation. Jensen and Middleton (5) reported a refined version of this method in 1970; however, neither method compensates for the variation in water requirement during development and may result in leaching of mobile nutrients from excessive irrigation during early growth.

The requirement for low soil water tension throughout snap bean growth and rapid redistribution of mobile nutrients, especially nitrate, with water movement through the soil profile (13), indicates the need for frequent N fertilizer applications in areas of substantial rainfall and soils with low ion exchange capacity. We determined the interactive effects of irrigation, N fertilization, and plant population on yield and quality of snap bean.

Materials and Methods

Experiments were conducted on Tifton loamy sand soil having an available water holding capacity of .091 cc of water per cc of soil. Fertilizer to furnish kg/ha rates of 112 N, 49 P, and 93 K was incorporated to a depth of 15 cm before planting.

Table 1. Rainfall, pan evaporation, and irrigation of snap beans (spring, 1974).

	Amount of water (mm)			
	Growth period (days from planting)			
Variable	0-26	27-36	37-62	Total
Rainfall	62	12	117	191
Pan evap	127	43	128	298
Irrigation				
High	3	23	38	64
Med	6	23	46	75
Low	10	15	38	63

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A split-plot design woth 2 replications was utilized for both the spring and fall crops with plant population as main plots, irrigation as sub-plots, and N levels as sub-sub-plots. 'Galagreen' snap beans were seeded in 30-cm and 91-cm rows and thinned to planting geometries of 30 x 8 cm and 91 x 4 cm.

Irrigation treatments utilizing pan evaporation as described by Jensen and Middleton (5) were:

Irrigation code	Amount per irrigation (mm)	Pan evaporation between irrigations (mm)		
		1st third foliage cover	2nd third foliage cover	3rd third foliage cover
High	8	23	15	8
Medium	11	30	23	15
Low	15	38	30	23

Nitrogen fertilization treatments were based on petiole nitrate analyses conducted at 4 to 7-day intervals. Calcium nitrate at the rate of 17 kg N/ha was applied as a topdress when petiole nitrate on a fresh wt basis was below the following levels:

Fertilization code	Petiole NO_3-N level (ppm)	
	Preblossom	Fruit development
High	1500	1000
Medium	1000	750
Low	750	500

NO_3-N was determined with an Orion nitrate ion electrode using a modification of the method reported by Baker (1). Twenty petioles of the youngest fully expanded leaves were collected between 8 and 9 AM and rinsed briefly in distilled water to remove possible external contamination. The central portion of the petioles was cut into 5-mm pieces and thoroughly mixed. Five g of petiole tissue was blended for 3 min with 200 ml of 0.025 M $Al_2(SO_4)_3$ solution containing 10 mg NO_3-N per liter. Blended tissue was transferred to a 250-ml beaker, allowed to stand for 15 min, and potential determined with stirring using the nitrate ion electrode attached to a Photovolt Model 112 pH meter. Removal of tissue particles by filtration or centrifugation did not appreciably affect readings and was not utilized. Nitrate extraction by this procedure yielded values which were 95-98% of the method of Baker (1).

Each plot was harvested when approx 40% of the pod wt was sieve 5 or greater. Plot length was 4.57 m and consisted of a single row of the 91-cm spacing or the 2 inside rows of a 4-row bed of 30-cm spacing. A 450 to 500 g sample of pods from each plot was graded to determine the exact size distribution and samples of sieve 5 pods were frozen for seed and fiber analyses. Seed and fiber were determined by the method of Kramer (9).

Results and Discussion

Spring 1974. Snap beans were planted April 16, started blooming the week of May 26, and were harvested June 15-18. The high N fertilization treatment required applications 29, 41, 49, and 55 days from planting. The medium N treatment required applications 34, 45, and 55 days from planting. The low-N treatment required applications 41 and 55 days from planting. In general, an application of N to the high N fertilization treatment was required within 3 to 4 days after a rain in excess of 2 to 3 cm.

Rainfall of 191 mm during the 62-day growing season (Table 1) was typical of the rainfall for this period of the year. The irrigation treatments were scheduled to apply different amounts of water, but due to the rainfall pattern the total water applied to each treatment varied only slightly. Total water applied was 85 to 89% of pan evaporation, which was slightly greater than the relationship of pan evaporation to water use by beans reported by Janes (4).

The number of irrigations and the maximum soil-water tension between irrigations of the 3 treatments were different (Table 2). A total of 9, 7, and 5 irrigations were required for the high, medium, and low irrigation treatments. The soil-water tension at the 15-cm depth was maintained at a relatively low level by all irrigation levels during the first 36 days of growth. Irrigating at the lowest frequency was sufficient to maintain the soil-water tension below .47 bar or about 60% available soil moisture during the 37- to 62-day growth period, which included blossom and fruit development. Irrigation applications at more frequent intervals reduced the maximum soil water tension between irrigations.

Table 2. No. of irrigations and maximum soil water tension between irrigation of snap, (spring, 1974).

Irrigation level	Growth period (days from planting)					
	0-26	27-36	37-62	0-26	27-36	37-62
	No. of irrigations			*Max tension (bar)*		
High	1	3	5	.15	.19	.31
Med	1	2	4	.17	.25	.41
Low	1	1	3	.22	.25	.47

Table 3. Effects of irrigation and N fertilization on yield of snap beans (spring, 1974).

Irrigation frequency	Snap bean yield (MT/ha)			
	N fertilization level			Irrigation effect
	High	Medium	Low	
High	12.2a[z]	10.0b	8.4cd	10.2a
Med	10.0b	9.9b	9.0c	9.6b
Low	8.1d	8.4cd	6.7e	7.7c
N effect	10.1a	9.4b	8.0c	

[z]Mean separation within N effect, irrigation effect and N fertilization x irrigation interactions by Duncan's multiple range test, 5% level.

Snap bean yield was about 2.2 MT/ha greater with the 30 cm x cm spacing compared to the 91 cm x 4 cm spacing. The response of the 2 plant populations to irrigation and N fertilization were similar; therefore, data in Table 3 are the averages of the 2 populations. A yield increase of about 2 MT/ha resulted when N fertilization (N effect) or irrigation frequency (irrigation effect) was increased. A combination of the high N fertilization and the high irrigation frequency increased yield to 12.2 MT/ha or an 82% increase over the low N and irrigation levels. The necessity of coordination of irrigation and fertilization practices was demonstrated by comparing yields of the medium N fertilization and irrigation frequency treatments with the yields resulting when either variable was increased independently. A high N fertilization or a high irrigation frequency did not increase pod yield when either was at the medium level. Both a high N fertilization and a high irrigation frequency tended to reduce yields below the medium levels when either variable was at the low level.

Snap bean quality as measured by percentage seed or fiber was not affected by irrigation or N fertilization, which is not in agreement with the results of Gabelman and Williams (3) and Kattan and Fleming (6). The maximum soil water tension between irrigations of .47 bar of the low irrigation frequency of this study was comparable to their most frequent irrigation

Table 4. Rainfall, pan evaporation and irrigation of snap beans (fall, 1974).

Variable	Amount of water (mm): Growth period (days from planting) 0-25	26-40	41-71	Total
Rainfall	25	16	25	66
Pan evap	120	58	90	268
Irrigation				
High	15	46	84	145
Med	23	34	69	126
Low	15	46	61	122

schedule. Kemp et al. (8), found that applying irrigation more frequently than needed to maintain the available soil moisture above 50% did not affect fiber development.

Fall 1974. Snap beans were planted Sept. 12, entered the blossom stage the week of Oct. 27, and harvested Nov. 21-25. The high N fertilization treatment required applications 26, 43, and 50 days from planting. The medium N treatment required applications 33 and 50 days from planting. The low N treatment required application 50 days from planting. The lower number of N applications required for the fall crop reflect the lower rainfall of 66 mm during this growing season (Table 4). The total pan evaporation, which would indicate potential water use, was less for the 71-day fall crop than for the 62-day spring crop. Total water applied to the low irrigation treatment was 70% of pan evaporation and is within the range reported by Janes (4). Differences in the soil water tension resulting from the irrigation treatments were slightly greater with the fall crop (Table 5) than with the spring crop. However, irrigating at the lowest frequency maintained the soil water tension below .67 bar or about 50% available soil moisture.

Table 5. Number of irrigations and maximum soil water tension between irrigation of snap beans (fall, 1974).

Irrigation level	Growth period (days from planting) 0-25	26-40	41-71	0-25	26-40	41-71
	No. of irrigations			*Max tension (bar)*		
High	2	6	11	.25	.15	.19
Med	2	3	6	.22	.27	.47
Low	1	3	4	.26	.36	.67

Yield of the 30 cm x 8 cm spacing was about 3.6 MT/ha greater than the 91 cm x 4 cm spacing in the fall crop. The greater yield increase with the higher population reflect a greater yield increase of the 30 x 8 cm spacing with the high N and irrigation treatments. The effects of irrigation and N fertilization on yield of the fall snap beans were similar to the spring crop response (Table 6). The lower yield of the spring crop may have resulted from nitrate leaching by heavy rainfall between tissue sampling periods causing short periods of low plant N status. The greater response from the high N levels (N effect) and the fewer number of N applications required would substantiate this conclusion.

Our results indicate that pan evaporation data can be used effectively to schedule irrigation of snap bean under varied climatic conditions. These data and results of an earlier study (14) both indicate that an irrigation frequency which allowed 8mm of pan evaporation between irrigations during blossom and pod development maintained the soil water tension at a low level and resulted in greater pod yields. The amount of water applied per irrigation at full foliage cover should be equal to the

Table 6. Effects of irrigation and N fertilization on yield of snap beans (fall, 1974).

Irrigation frequency	Snap bean yield (MT/ha): N fertilization level High	Medium	Low	Irrigation effect
High	13.8a[z]	10.0c	9.2d	11.0a
Med	11.6b	10.1c	8.9de	10.2b
Low	10.5c	8.5e	7.8f	8.9c
N effect	11.9a	9.5b	8.6c	

[z]Mean separation within N effect, irrigation effect and N fertilization x irrigation interaction by Duncan's multiple range test, 5% level.

amount of pan evaporation as suggested by Jensen (5). A high yield and a low soil water tension can be attained by either reducing the amount of water per irrigation (14) or by allowing a greater amount of pan evaporation between irrigations at earlier stages of growth. It appears that dividing the growth periods into 3 phases based on the percentage of maximum foliage cover will be sufficient for production purposes.

The data emphasize the importance of maintaining a high level of N fertilization to obtain the yield potential with optimum soil moisture. The greater number of N applications required during the heavy rainfall conditions of the spring crop and the redistribution of mobile nutrients reported by Rhoads (13) indicate that multiple applications of N may be required when snap beans are grown in sandy soils under moderate or heavy rainfall conditions.

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