Water and Nitrogen Interactions in Subsurface Drip Irrigated Broccoli and Cauliflower Production

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Abstract

Field experiments were conducted during the 1995-96 winter growing season at The University of Arizona's Maricopa Agricultural Center to determine the response of broccoli and cauliflower to a factorial arrangement of water rates and nitrogen (N) fertilizer rates. Both the broccoli and cauliflower experiments were randomized complete block factorial designs with three water levels (deficient, optimum, and excessive), four N fertilizer levels (deficient, suboptimal, supra optimal, excessive), and four replications. Drip tubing was buried at a depth of eight inches along the midline of each planting bed. Irrigation was applied daily as needed to maintain the predetermined target soil water tension levels and N fertilizer (urea ammonium nitrate solution) was applied in 4 or 5 split applications. Broccoli spears and cauliflower curds were harvested, weighed, and graded according to prevailing commercial practices. The optimum marketable yield of broccoli of 4.6 tons/acre was achieved with a total application of 18.9 inches of water and 267 lbs. N/acre. The optimum marketable yield of cauliflower of 9.5 tons/acre was achieved with a total application of 18.5 inches of water and 178 lbs. N/acre. For both crops a nitrogen deficiency had a greater negative impact on marketable yield than either deficient or excessive water application. Optimum marketable yields, earliness and head quality for both crops were achieved when the average soil water tension level for the entire season was maintained at about 10 cbars (or 13 cbars uncorrected gauge reading).

Introduction

California and Arizona are the first and second leading producers of broccoli and cauliflower in the United States. These two crops are harvested from 162,000 acres each year and have a total value of over $457 million. Much of the production in these two states is accomplished on arid and semiarid soils and represents about 92% of broccoli and cauliflower harvested annually in the United States (Bloyd and Kemerson, 1991).

Broccoli and cauliflower are highly dependent on inputs of irrigation water and N fertilizer to achieve optimum production in the southwestern U. S. (Beverly et al., 1986; Gardner and Roth, 1989; Gardner and Roth, 1990). Growers realize that these inputs must be carefully managed to ensure optimum yields and profits and minimal environmental impact.

Increasingly, growers are adopting production practices which allow them to significantly improve N and water use efficiency. Two such practices are conversion to drip irrigation systems and the use of in-season tissue nitrate tests to monitor the N status of the crop (Gardner and Roth, 1989; Gardner and Roth, 1990). Used together, these technologies offer almost unlimited flexibility in developing site specific nutrient management plans. The ability to inject multiple "split" applications of fluid N fertilizers directly through the drip system offers this flexibility in N management. The use of tissue nitrate testing provides the information growers need to avoid N deficiencies as well as unneeded N inputs.

This research is the third year of a three year study to evaluate the interactive effects of water and N fertilizer rate on the growth and marketable yield of broccoli and cauliflower when grown under subsurface drip irrigation. These and additional findings will be used to develop best management practices for these two crops.

Materials and Methods

Experiments were conducted during the winter growing season of 1995-96 at The University of Arizona's Maricopa Agricultural Center using Claudia broccoli and Candid Charm cauliflower. The experiments were randomized complete block factorial designs with three water levels (deficient, optimum, excessive), four N levels ranging from deficient to excessive, and four replications. A summary of the water and N treatments is shown in Tables 1 and 2.

The experiments were conducted on a Casa Grande sandy loam (fine-loamy, mixed, hyperthermic, typic Natrargid [reclaimed]). Prior to planting, the experimental area was exhaustively cropped with unfertilized Sudangrass to deplete residual N and reduce field variability. The Sudangrass was cut two times and all harvested material was removed from the field. Preplant N concentrations in the surface 4 feet of soil were 2.2 ppm $N0_3$ - N and 1.0 ppm NH_4 - N. Following the final Sudangrass harvest and subsequent tillage, the field was listed and bed-shaped (40 inch centers). A total of 280 lbs P_2O_5 /acre were broadcast applied as triple superphosphate (0- 45-0) prior to listing. Drip tubing (15 mil, Chapin Turbulent Flow) was injected down the midline of each planting bed at a depth of 8 inches. Seeds were planted into dry soil with 12.2 inches of water applied through the drip system to achieve germination. The "wet date" for both experiments was October 2. Individual plots were four beds wide and 40 feet long. The three soil water tension treatments were initiated at the end of the establishment period (17 days after planting) when both crops were at the one true leaf stage. All plots were thinned at the 4-6 leaf stage to final plant populations of 40,486 plants per acre (ppa) for broccoli and 12,146 ppa for cauliflower. These plant populations correspond to an interplant spacing of 8 inches for broccoli in two seedlines per bed and 13 inches for cauliflower in one seedline per bed.

Nitrogen was applied in 4 or 5 split applications as urea ammonium nitrate solution (UAN - 32% N) through the drip tubing. The N application schedule is shown in Table 2. Tensiometers were installed in all plots on October 17 at the 1 true leaf stage. Tensiometers were vertically inserted immediately adjacent to the drip tubing at a depth of 12 inches. The three soil water tension (i.e. irrigation) treatments were the three target tension levels as shown in Table 1. Tensiometers were read twice per week immediately prior to that day's irrigation event. Daily irrigation was scheduled based on these tensiometer readings. Table 1 shows the amounts of irrigation water applied and the actual mean seasonal soil water tensions at 12 inches. A total of 2.0 inches of precipitation was recorded during the growing seasons. All soil water tensions reported are corrected for the height of the water column in the tensiometer. The 12 inch placement of the tensiometer ceramic cup corresponds to a correction factor of 3 cbar. A corrected soil water tension value of 10 cbar is equivalent to an uncorrected gauge reading of 13 cbar.

Broccoli spears were harvested four times between January 25 and February 6. Spears were trimmed to a length of 8 inches and graded according to USDA standards (USDA Staff, 1943). Cauliflower curds were harvested three times between February 9 and were also graded according to USDA standards (USDA Staff, 1968). The length, weight, diameter, and basal stalk diameter were determined for broccoli spears while weight and diameter were measured for cauliflower curds. The harvest area used in individual plots was 33 sq. ft. for both crops.

Results and Discussion

Pronounced N x water treatment differences were visually apparent beginning at the 6-8 leaf stages for both crops and persisted and intensified as the season progressed. Results for total and marketable yield, mean curd/spear weight, mean curd/spear diameter, percent early harvested heads, and related quality data are shown in Tables 3 (broccoli) and 4 (cauliflower). In general, N deficiency had a much greater negative effect on marketable yield than did deficient or excessive water application rate for both broccoli and cauliflower. A severe N deficiency (the 90 lb. N/acre treatment) decreased marketable yield by an average of 85% and 49% for broccoli and cauliflower respectively. In contrast, the deficient water treatment decreased average marketable yield by only 9% and 14% for broccoli and cauliflower, respectively. The excessive water treatment had no consistent effect on the marketable yield of either crop.

In general, differences in N rate had a much more pronounced effect on head quality parameters for both crops. With broccoli, increasing N rate greatly reduced the percent of discolored spears (from 72% to 7%) and slightly increased the percent of spears harvested on the first two harvest dates (18% to 26%). With cauliflower, increasing N rates had no significant effect on the incidence of ricey curds but did increase the percent of curds in the first two harvest dates, from 35% at the deficient N rate to 66% at the excessive N rate (for optimum and excessive water levels only). There was no detection of hollow stem in either crop or fuzzy curds, green stems, off-color curds, or discolored jacket leaves for cauliflower.

Both crops matured very uniformly despite the wide range in water and nitrogen rates. Averaged across all water and N treatments, 84% of all broccoli spears were harvest-ready on two harvest dates spanning a 3-day period. For cauliflower, 96% of all curds were harvested on two dates over 5 days. This trend toward highly uniform stand establishment and maturation and relatively short harvest intervals of 3 to 5 days is consistent with previous research with drip irrigated broccoli and cauliflower. This desirable trait for commercial production of these crops is controlled somewhat by climatic influences and genetic characteristics, but appears to also be enhanced by the high degree of crop management uniformity that is attainable with drip irrigation.

Conclusions

Research of water x nitrogen interactions in subsurface drip irrigated broccoli and cauliflower over the past three years has shown that high marketable yields of broccoli (4.7 to 8.4 tons/acre) and cauliflower (9.4 to 14.9 tons/acre), excellent harvest quality and high crop maturation uniformity are consistently attainable. On a soil with very low residual nitrogen, optimum broccoli and cauliflower production has been achieved by applying a total of 220 to 270 lbs of N/acre in 4 to 5 split applications. Somewhat lower N rates would be needed for sites with higher levels of carryover soil N. Maintaining soil water tension levels (measured at the 12 inch depth) at 10 cbar throughout the growing season of both broccoli and cauliflower has been consistent with the attainment of optimum marketable yields and quality. On average this has required a total water application rate of 15.2 inches for broccoli and 16.3 inches for cauliflower.

References Cited

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Table 1. Water treatments for 1995-96.

Crop	Irrigation Treatment	Soil Water Tension		Water Applied[b]
		Target	Average[a]	
		cbar	cbar	inches
Broccoli	Deficient	20	25.0	16.2
	Optimum	10	12.3	18.9
	Excessive	4	4.0	27.7
Cauliflower	Deficient	20	23.2	15.0
	Optimum	10	10.0	18.5
	Excessive	4	4.0	27.9

[a]Average daily soil water tension measured at 12 in. depth.
[b]Plots also received 2.0 inches of rainfall. These totals include 12.2 inches of water applied to achieve germination and stand establishment.

Table 2. Application schedule for urea-ammonium nitrite solution for broccoli and cauliflower crops grown at the Maricopa Agricultural Center, 1995-96.

Crop	Date	DAP[a]	Growth Stage	N Level			
				1	2	3	4
				lbs N/a			
Broccoli	10/24	22	1-2 leaf	0	18	36	53
	11/14	43	4-6 leaf	18	36	53	80
	12/7	66	10-12 leaf	45	71	98	187
	1/3	93	1st buds	27	53	80	124
			Total	90	178	267	444
Cauliflower	10/24	22	1 leaf	0	18	36	53
	11/21	50	5-6 leaf	18	36	53	89
	12/13	72	8-10 leaf	27	44	71	133
	1/3	93	Folding	36	53	62	107
	1/25	115	Button	9	27	45	62
			Total	90	178	267	444

[a]DAP = Days after planting

Table 3. Total and marketable yield, spear weight, spear diameter, stalk diameter, % discolored spears and % early harvested heads for Claudia broccoli in response to water X N treatments.

SWT[a] Treatment	N Rate	Spear Yield		Spear Weight	Spear Diam.	Stalk Diam.	Discolored Spears	Early Spears
		Total	Market					
	lbs./acre	------- tons/acre -------		lbs.	-------- inches ---------		%	%
Deficient	90	3.0	0.9	0.17	2.6	0.9	58	18
Deficient	178	4.3	3.6	0.23	2.9	1.0	11	22
Deficient	267	4.8	4.3	0.26	3.1	1.1	11	15
Deficient	444	4.8	4.3	0.24	2.9	1.1	7	21
Optimum	90	3.0	0.4	0.15	2.4	0.9	81	18
Optimum	178	4.6	3.8	0.25	3.1	1.1	13	26
Optimum	267	5.0	4.6	0.26	3.2	1.1	11	23
Optimum	444	5.0	4.7	0.27	3.1	1.1	4	24
Excessive	90	2.9	0.8	0.15	2.4	0.8	77	18
Excessive	178	3.9	3.3	0.20	2.7	0.9	12	31
Excessive	267	5.0	4.6	0.26	3.1	1.0	10	32
Excessive	444	5.1	4.6	0.28	3.3	1.0	10	24
$LSD_{0.05}$		0.66	0.69	0.031	0.28	0.087	17.0	12.7

[a]SWT = Soil Water Tension

Table 4. Total and marketable yields, curd weight, curd diameter, % ricey curds and % early harvested heads for Candid Charm cauliflower in response to water X N treatments.

SWT[a] Treatment	N Rate	Curd Yield		Curd Weight	Curd Diam.	Ricey Curds	Early Curds
		Total	Market				
	lbs./acre	------- tons/acre -------		lbs.	inches	%	%
Deficient	90	6.3	6.0	0.97	5.2	5	52
Deficient	178	9.2	8.2	1.32	5.9	5	57
Deficient	267	7.8	7.3	1.16	5.6	3	38
Deficient	444	9.5	7.8	1.20	5.7	16	56
Optimum	90	5.7	5.0	0.80	5.0	5	35
Optimum	178	10.6	9.5	1.44	6.0	7	32
Optimum	267	9.6	8.9	1.39	6.0	7	63
Optimum	444	8.8	8.5	1.14	5.5	0	72
Excessive	90	5.0	3.6	0.70	4.6	7	35
Excessive	178	8.2	7.3	1.17	5.7	6	47
Excessive	267	9.0	8.7	1.36	6.0	0	54
Excessive	444	10.9	10.9	1.48	6.3	0	60
$LSD_{0.05}$		2.05	2.21	0.304	0.71	12.9	33.6

[a]SWT = Soil Water Tension