Nitrogen and Water Effects on the Growth, Yield and Quality of Drip-irrigated Sweet Corn

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Abstract

A complete factorial experiment using three nitrogen (44, 106 and 160 lbs N/acre) and three water rates (60, 100 and 130% consumptive use) examined the specific management criteria necessary for obtaining optimum yield and quality of drip-irrigated 'Jubilee' sweet corn. The crop was planted on 1 March and harvested on 10 June, with an 86/50°F heat unit accumulation of 1738. When present, a nitrogen deficiency greatly decreased marketable yield, number of marketable ears/plant, mean ear weight, ear length and tip fill. Higher moisture rates generally had less effect on yield and quality than did N rates; however, increasing water rates significantly increased marketable yields and plant height, improved tip fill and lessened the occurrence of blank kernels. The effect of N and water rates on N and dry matter accumulation and on diagnostic plant tissue testing results for sweet corn are also presented. The maximum marketable yield obtained in this experiment was 7.8 tons per acre, using 160 lbs N/acre and 21.1 inches of irrigation water.

INTRODUCTION

Drip irrigation interests vegetable growers because it potentially can improve water and fertilizer use efficiency, as well as increase yields and quality. This research was begun in 1987 (Stroehlein et al., 1988) to obtain information on water use-efficiency and the nutrient requirements of sweet corn, as well as the cultural practices necessary for obtaining high yields and quality using subsurface drip irrigation.

MATERIALS AND METHODS

<u>N and Water Effects on Yield and Quality</u> -- 'Jubilee' sweet corn was planted on 1 March, 1988 on east-west oriented 40-inch beds, using a commercial planter. Drip tubing lines (Chapin Twin-wall IV) were buried 15 cm below the center of each bed, using a tractor-mounted, 2-row injecting apparatus. The beds were relisted and smoothed with a commercial bed shaper to provide a flat, firm seedbed for more uniform seed placement and seedling emergence. A single seed row was planted on the south side of each bed to take advantage of solar radiation during the early season. The entire experimental area was treated uniformly until 12 April, when the corn was at the V4, or 4-leaf stage of growth (Ritchie et al., 1986). A total of 22 lbs N/acre and 5.82 inches of water were applied during the establishment period. On 13 April, three nitrogen (N) and three water rates were imposed in a complete factorial design with four replications. The actual amounts of N and water applied throughout the season are listed in Tables 1 and 2. All N was applied through the drip system as liquid urea-ammonium nitrate (Solution 32). The three water rates (I, II and III) were intended to supply 60, 100 and 130% of the consumptive use of sweet corn respectively, based on historical data (Erie et al., 1982). Water use was monitored with moisture depletion measurements made three times per week with a neutron moisture meter.

Table 1. Nitrogen fertilization schedule for drip irrigated sweet corn, Maricopa 1988.

Nitrogen Treatment	Amount of N Applied — Growth stages and dates: V1 3/29	V4 4/13	V6 4/20	V8 5/4	Total
	-------lbs N/acre-------				
N1	22	9	13	0	44
N2	22	22	40	22	106
N3	22	40	62	36	160

Table 2. Irrigation schedule for drip irrigated sweet corn, Maricopa, 1988.

Date(s)	Water Applied* I	II	III
	-------inches-------		
March 3 - 6	5.82	5.82	5.82
April 15	0.11	0.51	0.68
20	0.10	0.37	0.48
27	0.30	0.42	0.60
29	----	0.45	0.65
May 2	----	0.50	0.68
4	0.16	0.50	0.66
6	----	0.57	0.79
9	0.24	0.63	0.80
11	0.41	0.68	0.92
13	0.41	0.74	1.04
16	0.69	1.21	1.62
18	0.62	1.07	1.40
20	0.40	0.80	1.05
23	1.31	1.95	2.60
25 - 31	1.15	1.74	2.63
June 1 - 10	2.18	3.13	4.56
Total	13.90	21.09	26.98

*Rainfall during the period totaled 1.18 inches.

Each plot was 6 rows wide and 50 feet long. The estimated amounts of nitrate-N contained in irrigation treatments I, II, and III were 5, 8 and 10 lbs per acre, respectively. The electrical conductivity of the irrigation water was 1.1 mmhos/cm (700 ppm). The preplant level of pH and nitrate-N in the surface foot of soil were 8.5 and 3.5 ppm respectively. Plants were hand-thinned to a population of 20,000 per acre at the V6 stage.

Corn was harvested on 10 June, the optimum maturity date for the majority of the plots. In general, the plots receiving adequate water and N matured 2 to 3 days before the low N plots. Numerous yield and quality parameters were measured at harvest; they are summarized in Tables 3 and 4.

Table 3. Yield and quality of 'Jubilee' sweet corn as affected by N and water rates, Maricopa, 1988.

Treatment		Total Ears	Marketable Ears	Total Wt. Ears	Marketable Wt. Ears	Ear Weight + husk	Ear Weight - husk	Ear Length	Ear Diam.	Ratings* Tip Fill	Ratings* Blank	Sugar Content	Plnt Ht.
		-----no./acre-----		-------lbs/acre------		grams		inches		1 - 5		°Brix	feet
N1	W1	17,880	5,570	7,480	3,310	272	168	5.6	1.8	2.0	3.3	26.9	5.6
N2	W1	22,260	16,360	12,350	10,290	286	206	6.8	1.8	3.8	3.5	25.0	5.8
N3	W1	30,360	17,710	14,470	12,000	308	200	6.8	1.8	2.5	3.1	23.9	5.7
N1	W2	17,200	5,060	7,980	3,050	272	180	5.9	1.7	2.2	4.4	27.3	6.5
N2	W2	24,630	16,870	13,840	10,610	285	200	6.5	1.8	2.8	4.2	26.5	7.2
N3	W2	29,010	22,440	18,620	15,660	318	223	6.6	1.8	3.8	4.4	26.0	7.1
N1	W3	17,710	6,070	7,460	3,440	255	167	5.5	1.7	2.0	4.5	27.5	6.5
N2	W3	24,120	18,550	14,680	12,360	303	209	6.4	1.8	3.5	4.6	26.9	7.4
N3	W3	28,000	21,430	17,320	14,520	308	200	7.0	1.8	3.9	4.2	26.5	7.7

*Rating used ranged from 1 (Worst) to 5 (Best) for tip fill and blank kernals.

Table 4. Overall means of sweet corn parameters as affected by N and water rates, Maricopa, 1988.

Treatment	Total Ears	Marketable Ears	Total Wt. Ears	Marketable Wt. Ears	Ear Weight + husk	Ear Weight - husk	Ear Length	Ear Diam.	Ratings* Tip Fill	Ratings* Blanks	Sugar Content	Plnt Ht.
	-----no./acre-----		------lbs./acre-----		----grams----		----inches----		1 - 5		°Brix	feet
N Rate												
1	17,600a	13,210a	7,640a	3,270a	266a	172a	5.7a	1.7	2.3a	3.9	27.2a	6.2a
2	23,670b	17,260b	13,620b	11,090b	291b	205b	6.6b	1.8	3.4b	4.1	26.1ab	6.8b
3	26,900c	20,530c	16,800c	14,060c	311c	209b	6.8b	1.8	3.4b	3.9	25.5b	6.8b
Water Rate												
I	21,310a	13,210a	11,440a	8,530a	289	193	6.3	1.8	2.8a	3.3a	25.3	5.7a
II	23,620b	14,790ab	13,490b	9,770b	289	201	6.4	1.8	3.0ab	4.3b	26.6	6.9b
III	23,280b	15,350b	13,160b	10,100b	292	192	6.4	1.8	3.3b	4.5b	27.0	7.2c

*Ratings used ranged from 1 (Worst) to 5 (Best) for tip fill and blank kernals.

Tissue Testing and N Efficiency Studies -- Basal stalk and earleaf tissues were sampled and analyzed to help evaluate the fertility and water treatments and to develop sound diagnostic guidelines for nitrogen management in sweet corn. Six to ten corn plants were randomly selected from the 9 N x Water plots at the V4, V6, V7, V8, V11, VT and R1 growth stages. Basal stalk samples were obtained by discarding all root and leaf tissue and any stalk tissue that was greater than 4 in. above ground level. Any leaf sheath tissue occurring in the 0 to 4 in. segment was included in the basal stalk sample. All stalk tissue was immediately split longitudinally to hasten drying at 60°C. Samples were ground to pass a 30-mesh screen and analyzed for NO_3-N by ion selective electrode. Nitrate concentrations for the three N levels were plotted versus time for the three water levels (Figure 1).

Although established tissue sampling guidelines are not available for sweet corn, the earleaf opposite and just below the primary ear is normally sampled for field corn. This would correspond to the leaf adjacent to the secondary ear in most sweet corn varieties. Because the primary earleaf is somewhat more easily identified and sampled, both primary and secondary earleaves were sampled for comparison. At the R1 growth stage (silking), the earleaves adjacent to the primary and secondary ears were sampled from 10 randomly selected plants within each plot. Samples were dried at 60° and ground to pass a 30-mesh screen. Nitrogen content was determined on Kjeldahl digests, using steam distillation. From nitric-perchloric digests, Ca, Mg, K, Ca, Fe, Zn and Mn were determined by atomic absorption spectrophotometry.

Dry matter and N accumulation during the growing season were determined by sampling all aerial plant tissue from $1m^2$ areas within all plots. Nitrogen uptake was calculated as the product of dry matter production and the N concentration. Samples were collected at the V4, V6, V8, V11, VT and R3.5 growth stages from three replications. Plants from the first three sampling dates (V4 through V8) were handled as whole plants; the plants collected from V11 through R3.5 were subdivided into the categories of leaves, stalk plus tassel, grain, cob plus shank and husk plus silk in accordance with the maturity of the corn on a specific sampling date. Plant parts were dried at 60°C, ground to pass a 30-mesh screen and analyzed for Kjeldahl N (organic + ammonium-N) by steam distillation.

RESULTS

N and Water Effects on Yield and Quality -- Every yield and quality parameter measured was significant, except for ear diameter. There was a strong trend toward increasing diameter with increasing N rates (significant at the 9% level), in 1987 significant differences were found with N treatments. Nitrogen nutrition apparently has a greater influence on ear diameter than water.

Number of total ears, number of marketable ears, total weight of ears, and total marketable ears were increased by N and water rates. Individual ear weight (with and without husks) and ear length were increased with increasing N rates; water rates had little effect on these parameters. Tip fill of ears was increased by increasing both N and water. Blank kernels were increased with the low water rate. Cull weights increased inversely with N rates but were not effected by water rate. Sugar content decreased as N increased; possibly this was an effect on maturity of physiology of the corn as ears from N deficient plants were about 2 to 3 days behind those grown in N-sufficient plots. Plant heights were increased strongly by increasing water rates although the plants were significantly shorter only for the lowest N rate.

Tissue Testing and N Efficiency Studies -- Results of earleaf chemical analyses are shown in Table 5. Nutrient content patterns in earleaves tended to be very complex; they usually included first and second order treatment interactions. In most cases, the trends in the nutrient concentrations contained in leaves opposite the first and second ears (labeled Earleaf-1 and Earleaf-2, respectively) were similar. In the case of mobile nutrients such as Mg and K, the concentrations measured in the lower earleaf (No. 2) were greater than those observed in the top earleaf. This strongly suggests that adequate amounts of these nutrients were available to the plants; remobilization of these nutrients to younger plant tissue was not necessary for optimum growth. In the case of N (also a mobile nutrient), plants treated with nitrogen levels 1 and 2 were N-deficient; however, nitrogen level 3 resulted in plants with adequate N. In plots where N was deficient, lowest concentrations of N were measured in the second earleaf; in N-sufficient plots, the second earleaf samples showed the highest N content. In other words, the N content of the second earleaves appears to be a more sensitive indicator of N status in sweet corn at the R1 stage compared to the N content of the primary earleaf. The relationship between marketable yield of sweet corn and No. 2 earleaf N content indicates a "critical level" of 2.5% ammonium + organic-N at the R1 stage. This is consistent with our 1987 results plus those of Painter and Simpson (1969) from Idaho.

For the immobile nutrients Ca, Zn and Cu, concentrations in the second earleaf tended to be greater than the concentrations in the first earleaf. Little practical difference in the concentrations of Mn and Fe showed in either earleaf tissue.

Table 5. Chemical analyses of earleaves of sweet corn as affected by nitrogen and water rates, Maricopa, 1988.

			Water Level								
			I			II			III		
		Earleaf	NI			NII			NIII		
Nutrient	Units	Position	1	2	3	1	2	3	1	2	3
N	%	1	1.36	1.96	2.39	1.46	1.86	2.35	1.18	1.86	1.99
	%	2	1.32	1.81	2.48	1.30	1.67	2.32	1.03	1.68	2.12
K	%	1	1.67	1.58	1.60	1.75	1.76	1.64	1.28	1.59	1.67
	%	2	1.64	1.75	1.78	1.73	1.74	1.84	1.81	1.92	1.96
Ca	%	1	0.56	0.66	0.68	0.60	0.70	0.74	0.64	0.77	0.75
	%	2	0.57	0.75	0.82	0.66	0.73	0.76	0.76	0.76	0.78
Mg	%	1	0.26	0.32	0.28	0.28	0.31	0.35	0.24	0.30	0.33
	%	2	0.32	0.34	0.37	0.33	0.38	0.41	0.31	0.35	0.42
Fe	ppm	1	218	205	232	167	188	168	157	199	190
	ppm	2	184	201	204	199	195	190	192	196	205
Zn	ppm	1	20	31	32	12	20	19	10	18	20
	ppm	2	17	33	36	17	24	18	15	18	31
Mn	ppm	1	172	248	302	144	227	262	113	186	242
	ppm	2	188	231	264	164	246	256	127	205	243
Cu	ppm	1	12	19	19	8	12	18	8	12	20
	ppm	2	17	21	18	17	18	18	21	20	26

In general, the highest nutrient concentrations for all of the elements tested were in samples from plots receiving adequate or greater levels of N and water (water treatments II and III and N treatments 2 and 3). The lowest nutrient concentrations were in plants with N deficiency and moisture stress. The application of N resulted in the stimulation of uptake for virtually all of the nutrients investigated. Kamprath (1987) documented enhanced P uptake in response to N fertilization in field corn; similar effects were observed here for Mn (particularly evident), K, Ca, Mg, Zn and Cu in sweet corn. Applying 160 lbs N/acre increased Mn content in the second earleaves by 91%, compared to plants receiving only 44 lbs N/acre.

Increasing soil acidity and decreasing soil redox potential are the two most influential factors in promoting Mn availability to plants. At the V11 stage, soil samples were obtained in III-1 and III-3 treated plots to examine the effects of increasing N application rates on the possible occurrence of localized areas of acidification within the root zone. The sample date (10 May) was selected to coincide with the expected maximum potential acidification of the root zone due to N application.

The final N fertilizer application was made on 4 May. Therefore, by the date samples were obtained, nitrification of applied ammonium-N should have been essentially completed and acidification of the root zone should have been maximized. Soil pits were dug perpendicular to the plant row to a depth of 24 inches and extended 12 inches to the right and left of the plants. From this 24 x 24 in. area, samples were taken on a 4 in. grid pattern; also, one sample was taken immediately below the drip tubing. Soil was obtained by drilling a 1.5 in. hand auger horizontally into the soil profile for a distance of 6 to 8 in. The pH of a saturated paste extract from each soil sample was determined.

The pH values measured ranged from 7.5 to 8.0 in all samples. No zones of depressed soil pH were identified in either of the pits. Even the pH of the soil directly below the drip tubing was not appreciably different from that measured in the rest of an entire pit. Therefore, enhanced Mn uptake by sweet corn in response to subsurface applications of urea-ammonium nitrate is not the result of localized soil acidification. The Mn content of second earleaves consistently decreased with increasing levels of water application (Table 5). This phenomena was also observed in 1987 and strongly suggests that any decrease in redox potential associated with increasing water application is not sufficient to enhance the availability of soil Mn to sweet corn plants.

Basal stalk nitrate values were very responsive to the N fertilizer treatments (Figure 1). Prior to the V10 stage, the highest nitrate levels were observed in the Water II treated plots. In the latter portion of the vegetative growth period, the highest levels of nitrate in stalk tissue were observed in the Water I plots. It is hypothesized that this is the result of reduced leaching and greater positional availability of N during the later portions of the season in the Water I plots. The interpretation of basal stalk nitrate levels in 1988 was very similar to that for 1987. A proposed interpretation of basal stalk nitrate levels in sweet corn for the vegetative growth period is shown in Figure 2.

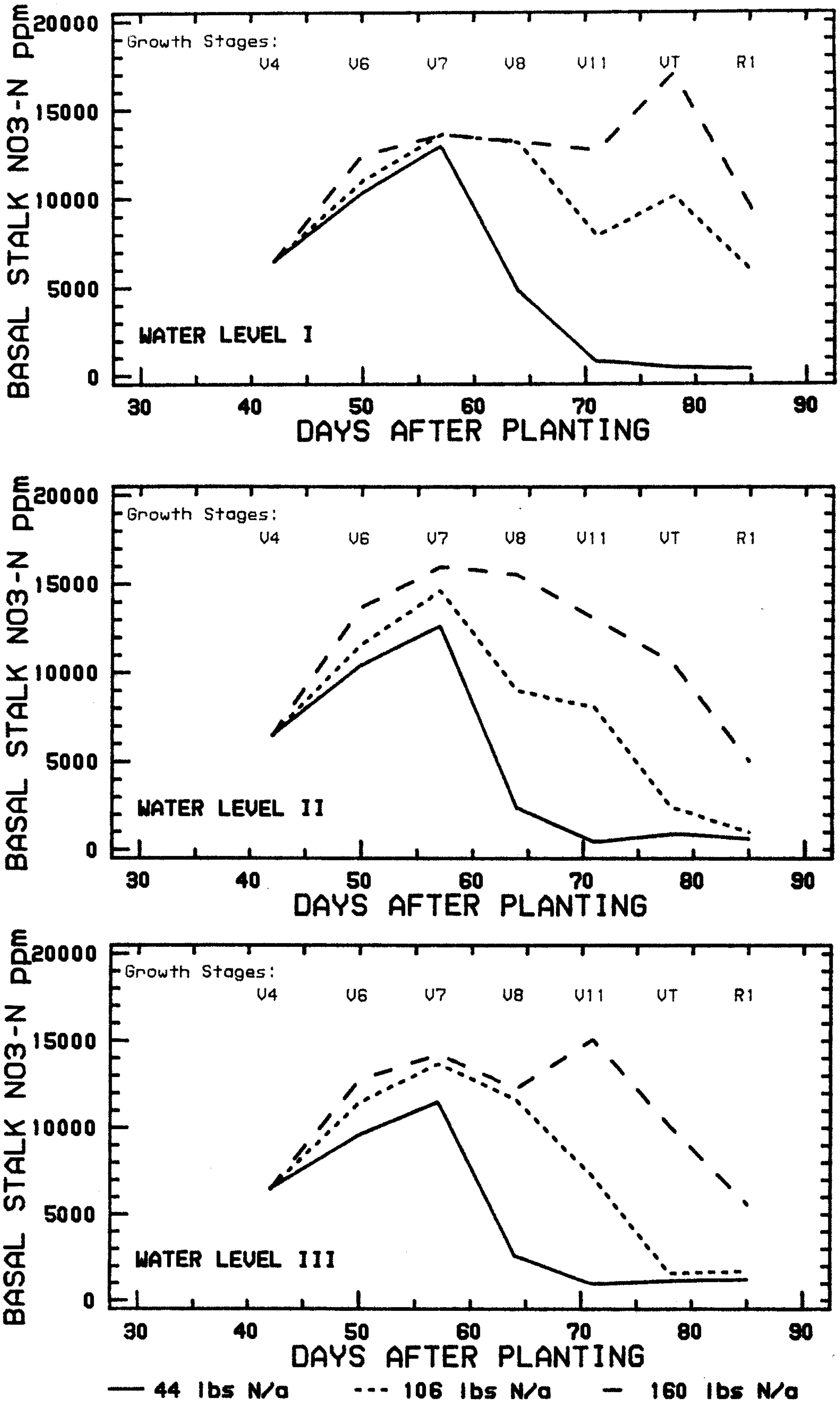


Figure 1. Nitrate content of basal stalks of 'Jubilee' sweet corn for three N rates at Water Level I (top), II (middle) and III (bottom).

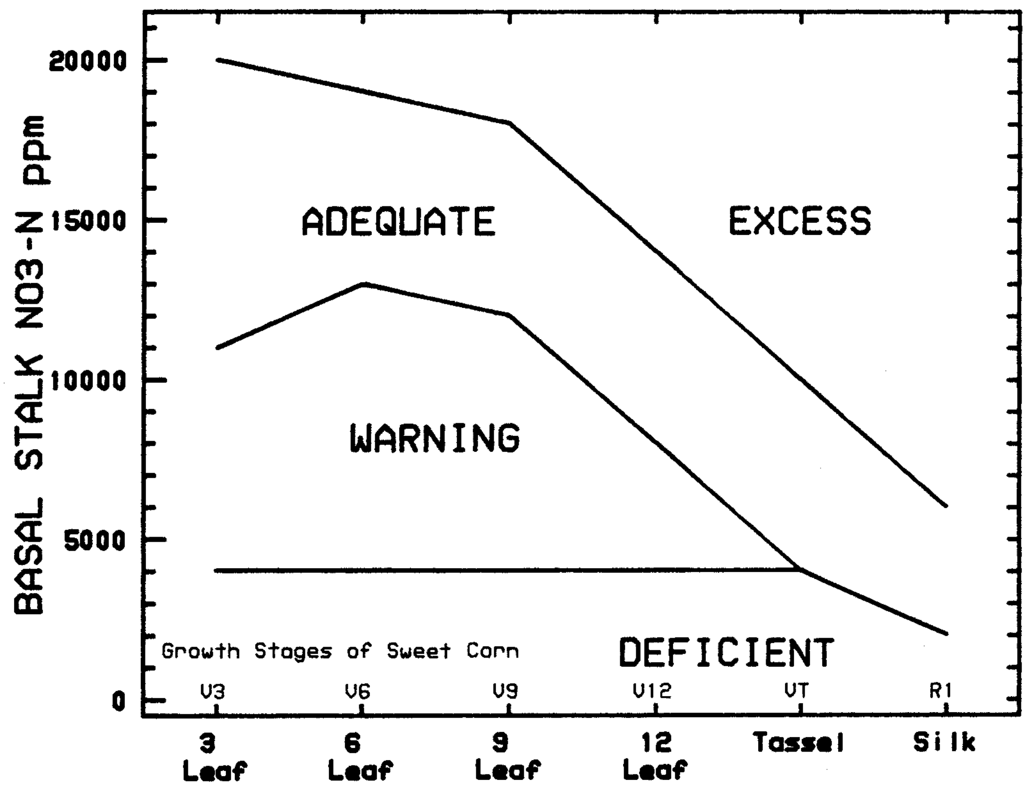
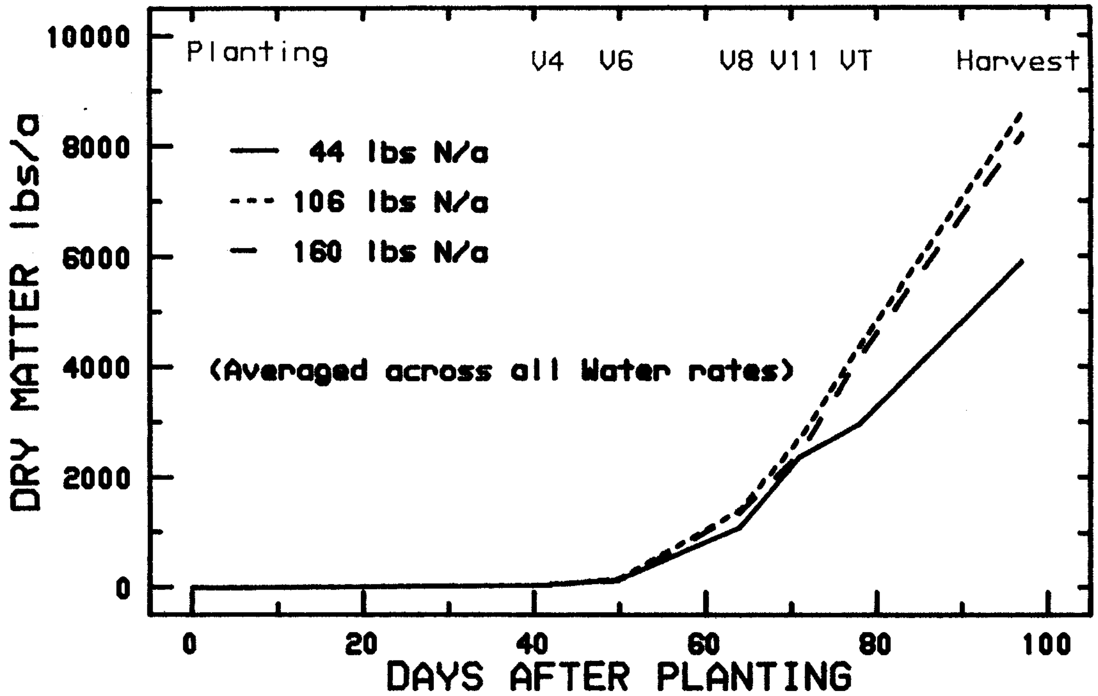


Figure 2. Proposed interpretation of basal stalk nitrate values for sweet corn during the vegetative growth period.

Dry matter accumulated at a nearly linear rate from the V8 stage until harvest. Increasing the N rate had a much greater effect on dry matter accumulation in this experiment than did increasing the water rate (Figures 5 and 6). Nitrogen uptake was nearly complete by the VT stage and increased only slightly after that time (Figures 7 and 8), confirming our findings in 1987. This pattern of seasonal N uptake differ considerably from that of many field corn hybrids, which may take up 40 to 50% of their total N supply after the VT stage. The highest N accumulations were measured in the lowest water plots (Water Level I), although increasing the water rate had much less effect on total N uptake than did increasing N rates.



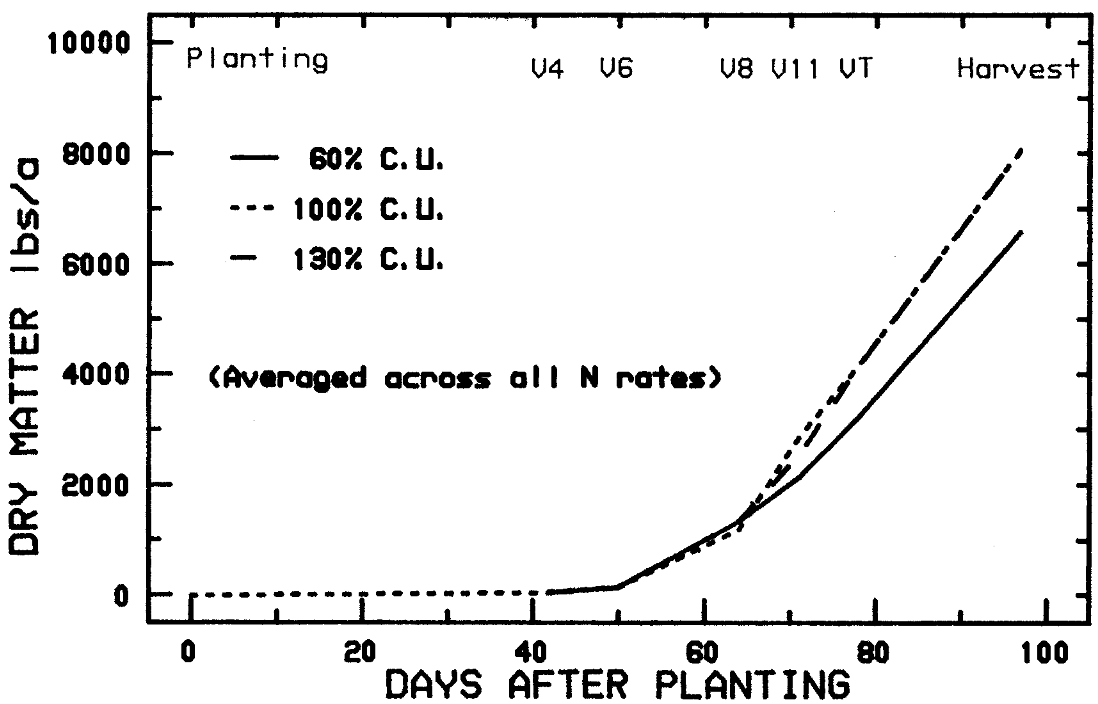
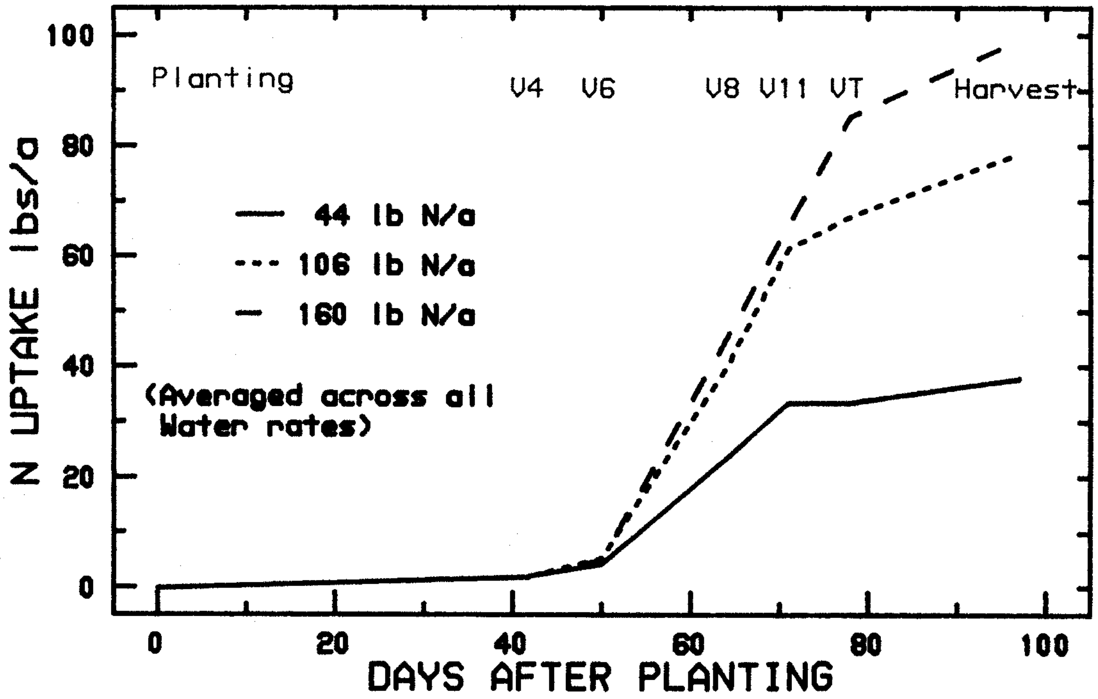


Figure 3. Seasonal accumulation of dry matter in 'Jubilee' sweet corn as affected by N rates (top) and water rates (bottom).



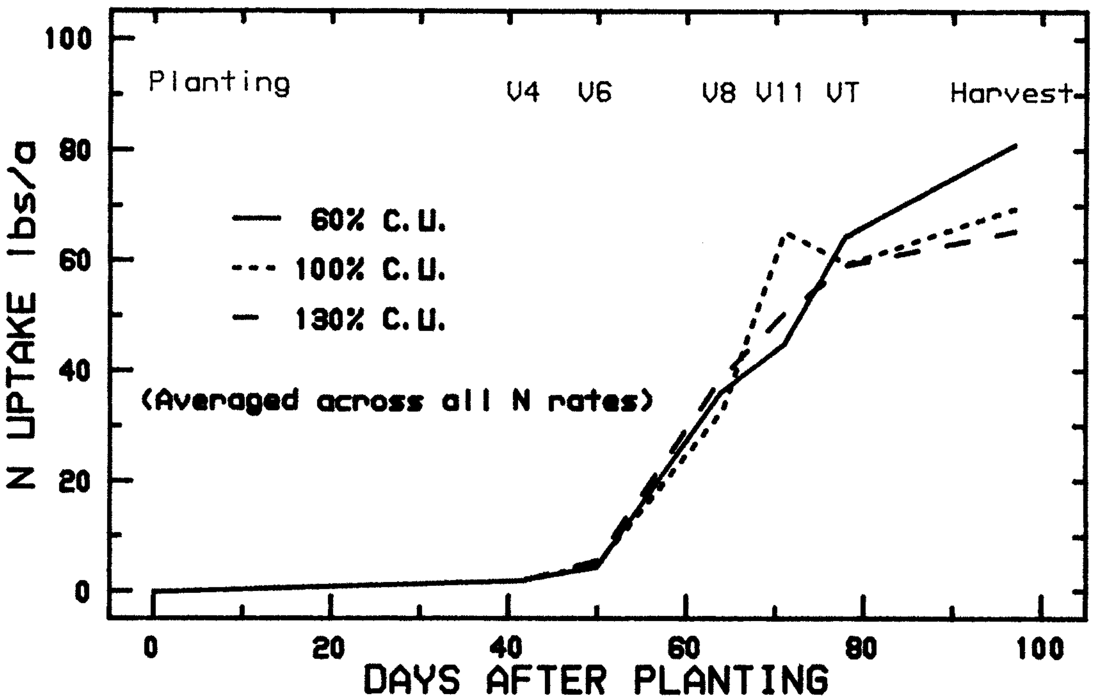


Figure 4. Seasonal accumulation of nitrogen in 'Jubilee' sweet corn as affected by N rates (top) and water rates (bottom).

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