Effects of Nitrogen and Water Rates on Nitrogen Uptake Dynamics in Drip Irrigated Sweet Corn

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ABSTRACT

A complete factorial experiment using three nitrogen (67, 156 and 245 lbs N/acre) and three water rates (70, 100 and 130% consumptive use) examined the specific management criteria necessary for obtaining optimum yield and quality of drip-irrigated 'Sweetie '82' sweet corn. The crop was planted on 22 February and harvested on 30 May with an 86/50° F heat unit accumulation of 1444. 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. 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 7.2 tons per acre, using 245 lbs N/acre and 20.5 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, Doerge et al, 1989) 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

N and Water Effects on Yield and Quality 'Sweetie '82' sweet corn was planted on 22 February 1989 on east-west oriented 40-inch beds, using a commercial planter. This cultivar is an improved Super Sweet corn which produces 255% more sugar than normal sweet corns. It has 75% Sh_2 and 25% SU + Sh_2 genes. Drip tubing lines (Chapin Twin-wall IV) were buried 8 inches 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 28 March, when the corn was at the V3, or 3-leaf stage of growth (Ritchie, et al, 1986). A total of 6.1 inches of water was applied during the establishment period. On 29 March, 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 70, 100 and 130% of the consumptive use of sweet corn respectively, based on historical data (Erie, et al, 1982). Water use from each plot was monitored with moisture depletion measurements made three times per week with tensiometers and a neutron moisture meter.

Water was applied daily with water rates being adjusted each Monday for the following week.

Table 1. Nitrogen fertilization schedule for drip irrigated sweet corn, Maricopa, 1989.

Nitrogen Treatment	Amount of N Applied, Growth Stages and Dates: V3 3/29	V5 4/6	V8 4/19	V12 4/26	VT 5/8	Total N
	------------------- lbs N/acre -------------------					
N1	9	18	31	9	0	67
N2	18	36	58	31	13	156
N3	27	58	89	44	27	245

Table 2. Irrigation schedule for drip irrigated sweet corn, Maricopa, 1989.

Date(s)	Water Treatments: WI	WII	WIII
	----------- inches applied -----------		
23 Feb. - 28 Mar.	6.10	6.10	6.10
29 Mar. - 3 Apr.	0.16	0.35	0.20
4 Apr. - 10 Apr.	0.24	0.43	0.55
11 Apr. - 17 Apr.	0.39	0.98	1.22
18 Apr. - 25 Apr.	0.87	1.65	2.09
26 Apr. - 1 May	0.63	1.34	1.65
2 May - 5 May	0.55	0.98	1.30
6 May - 10 May	0.83	1.54	2.13
11 May - 16 May	1.02	1.81	2.56
17 May - 22 May	1.34	2.48	3.27
23 May - 25 May	0.67	1.18	1.61
26 May - 30 May	0.98	1.61	2.40
Total	13.78	20.47	25.08

Each plot was six rows wide and 50 feet long. The estimated amounts of nitrate-N contained in irrigation treatments I, II, and III were 8, 12 and 14 lbs per acre, respectively. The electrical conductivity of the irrigation water was 1.0 mmhos/cm (640 ppm). The preplant pH and level of nitrate-N in the surface foot of soil were 8.5 and 1.2 ppm respectively. Plants were hand-thinned to a population of 20,000 per acre at the V6 stage.

Corn was harvested on 30 May, the optimum maturity date for the majority of the plots. In general, the plots receiving adequate water and N matured two to three days before the low N plots.

Plant heights were measured at harvest time. Harvest data were collected on total number and weight of ears, number and weight of marketable ears and culls. Ten randomly selected marketable ears were husked, weighed, length and diameter were measured, and tip fill and blank kernels were estimated. The numbers of marketable ears and culls per plant were calculated. Sugar content (Brix) was determined on extracted kernel milk with a refractometer.

Tissue Testing and N Uptake 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 10 corn plants were randomly selected from the 9 N x Water plots in each replication at the V5, V6, V8, V10, 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.

At the R1 growth stage (silking), the ear leaves adjacent to the 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. Total nitrogen content was determined using an automated CNS Analyzer (Dumas method).

Dry matter and N accumulation during the growing season were determined by sampling all aerial plant tissue from 1 m^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 V5, V6, V8, V10, VT, R1 and R3.5 growth stages from three replications. Plants from the first three sampling dates (V5 through V8) were handled as whole plants; the plants collected from V10 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 total N with an automated CNS Analyzer.

RESULTS

N and Water Effects on Yield and Quality

Differences in N rate consistently had a greater effect on yield and quality parameters than did differences in water rates (Tables 3 and 4). This confirms the findings in 1987 and 1988 (Stroehlein, et al, 1988 and Doerge, et al, 1989). Alleviating N deficiency dramatically improved marketable ear yield by increasing ear size and number of marketable ears per plant. In addition, increasing N rate resulted in longer ears, taller plants and improved tip fill. The sugar content of kernel milk decreased significantly as N rate was increased. This was probably due to the effect of increasing N rate on the maturity of the ears on the harvest date. Ears from N deficient plots (N1) were about two to three days behind those grown in N sufficient plots (N2 and N3). N rates had little effect on ear diameter and occurrence of blank kernels.

Increasing the water rate from 70 to 100% of consumptive resulted in modest improvement in marketable ear yield but had no effect on any of the ear quality parameters. Increasing the water rate from 100 to 130% of consumptive use did not significantly affect any yield or quality parameters. There were no water x N interactions.

Tissue Testing and N Uptake Studies

The concentration of nitrate in basal stalk tissue continued to be the best indicator of the N status of sweet corn in 1989 for the cultivar 'Sweetie '82'. In 1989, stalk tissue was collected six times during the season and results are shown in Fig. 1. Stem nitrate concentrations were not significantly affected until 45 days after planting due to the relatively low growth rate and minimal N uptake. Differences in N treatments quickly separated with time corresponding to the period of most rapid growth and N uptake. The application of N at the V8 growth stage (Table 1) temporarily increased the stalk nitrate levels in the N1 plots. However, visual N deficiency symptoms were again observed in these plots by the V11 to V12 stage when stalk nitrate levels dropped below 4000 ppm NO_3-N.

Table 3. Yield and quality of 'Sweetie '82' sweet corn as affected by N and water rates, Maricopa, 1989.

Treatment		Total Ears	Marketable Ears	Total Wt. Ears	Marketable Wt. Ears	Ear - Husk Weight	Ear Length	Ear Diam.	Ratings* Tip Fill Blank	Sugar Content	Plant Height
		---- no./acre ----		----- lbs/acre -----		grams	inches		1 - 5	°Brix	feet
N1	W1	15,182	6,073	5,870	3,144	170	6.2	1.8	3.35.0		
19.0	5.4										
N2	W1	18,891	15,518	10,029	8,969	184	6.5	1.8	3.34.6		
18.0	5.1										
N3	W1	21,595	17,883	12,389	11,374	211	6.8	1.9	3.85.0		
17.0	5.3										
N1	W2	15,518	7,085	6,074	3,634	163	6.0	1.8	3.05.0		
19.6	6.5										
N2	W2	19,401	16,870	11,481	10,510	208	6.8	1.9	3.84.9		
18.3	6.7										
N3	W2	27,328	20,073	16,059	14,331	236	7.2	2.0	4.35.0		
17.4	7.0										
N1	W3	19,903	9,951	8,274	5,469	175	5.1	1.7	3.05.0		
19.4	6.5										
N2	W3	22,773	17,543	13,387	11,597	219	6.9	1.9	3.95.0		
18.4	6.8										
N3	W3	27,158	20,243	15,970	13,984	223	7.0	1.9	4.35.0		
17.5	7.0										

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

Table 4. Overall means of sweet corn parameters for N and water rates, Maricopa, 1989.

Treatment	Total Ears	Marketable Ears	Total Wt. Ears	Marketable Wt. Ears	Ear - Husk Weight	Ear Length	Ear Diam.	Ratings* Tip Fill	Ratings* Blank	Sugar Content	Plant Height
	---- no./acre ----		----- lbs/acre -----		grams	inches		1 - 5		°Brix	feet
N Rate											
1	16,870c**	7,704c	6,743c	4,079c	170c	5.7b	2.1	3.1c	5.0a	19.3a	6.1b
2	20,356b	16,644b	11,632b	10,359b	204b	6.7a	1.9	3.6b	4.8b	18.2b	6.2b
3	25,360a	25,360a	14,803a	13,227a	223a	7.0a	1.9	4.1a	5.0a	17.3c	6.4a
Water Rate											
I	18,555b	13,158b	9,432b	7,829b	189	6.5	1.8	3.4	4.9	18.0	5.2b
II	20,749ab	14,676ab	11,205a	9,495a	202	6.6	1.9	3.7	5.0	18.4	6.7a
III	23,279a	15,915a	12,550a	10,350a	206	6.4	2.2	3.7	5.0	18.4	6.8a

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

**Mean values in each column which are followed by the same letter are not significantly different at the 5% level of probability according to the Duncan's Multiple Range test.

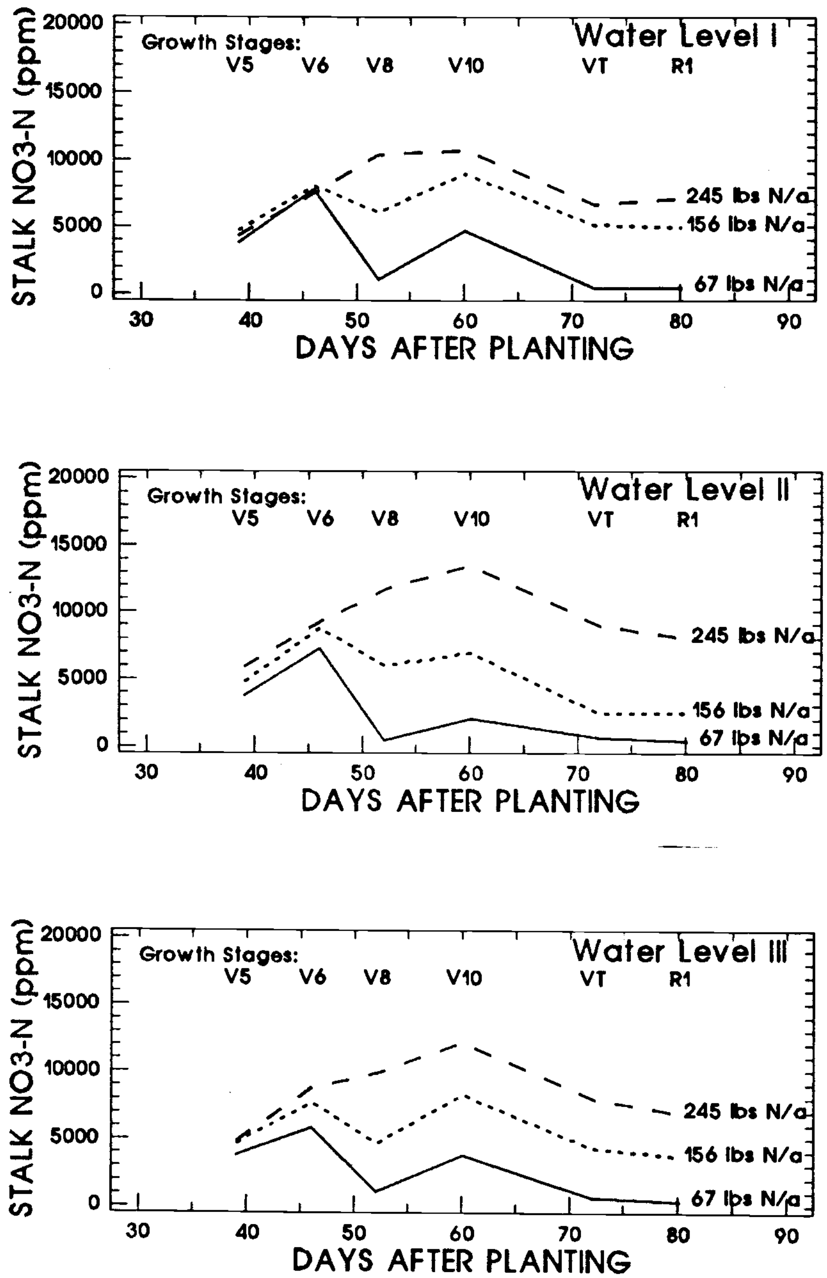


Figure 1. Nitrate concentrations in basal stalk tissue of 'Sweetie '82' sweet corn receiving 70% (Water Level I), 100% (W.L. II) and 130% (W.L. III) of consumptive use.

Increases in N rate consistently resulted in corresponding increases in basal stalk nitrate content in plants from N2 and N3 plots. This responsiveness of stalk nitrate content to N supply has been observed in each of the three site - years of this work regardless of the cultivar grown. An interpretation of basal stalk nitrate levels in sweet corn for the vegetative growth period is shown in Figure 2.

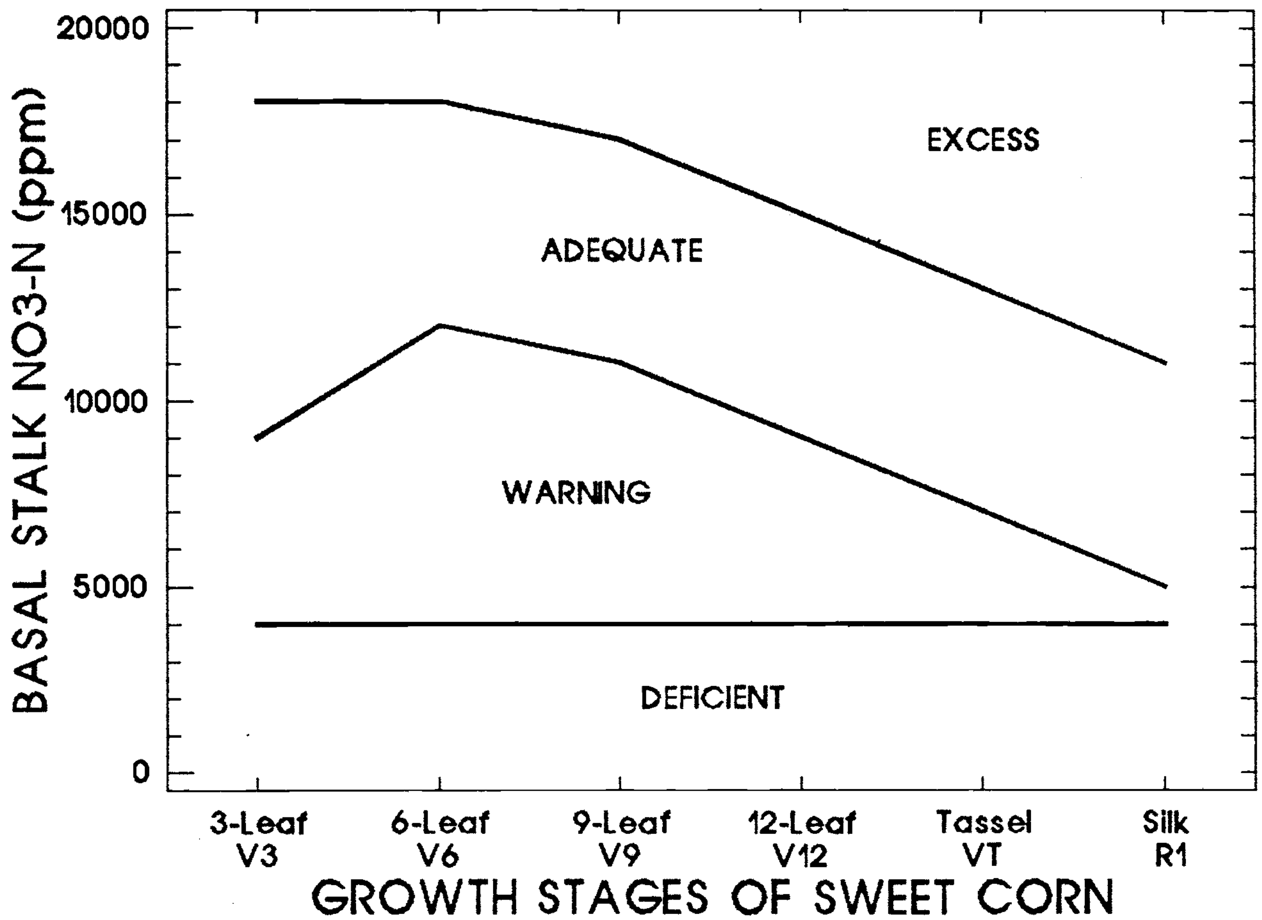


Figure 2. Interpretation of basal stalk nitrate levels in sweet corn during the vegetative growth period.

The total N content in earleaf samples taken at the R1 stage (early silking) consisting of the earleaf immediately below and opposite the primary ear again proved to be a good indicator of yield potential in sweet corn. A critical nutrient range of 2.7% to 3.0% N was observed in 1989 (Figure 3). This is slightly higher than the 2.1% to 2.6% range observed in 1987. Additional data on the relationship between earleaf N concentration and ear yield will be collected in 1990 from plots covering a wide range in N availability.

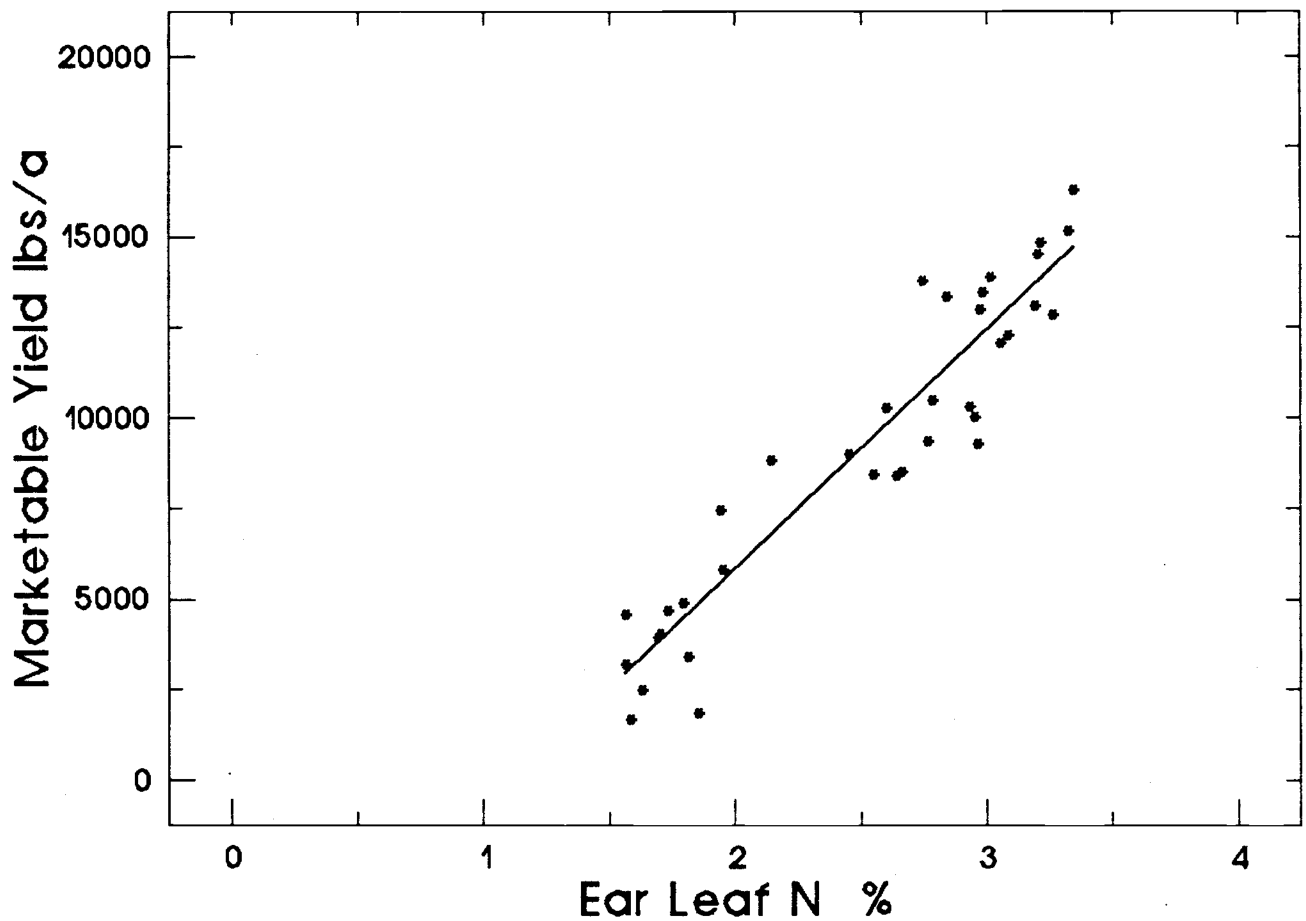


Figure 3. Relationship between marketable yield of 'Sweetie '82' sweet corn and total N concentrations in ear leaves at the R1 stage.

Rates of dry matter accumulation with time and daily flux as affected by N and water rates are shown in Figures 4 and 5. Nitrogen had a greater effect in increasing dry matter accumulation than did water rates. Water and N treatments were begun on 29 March, 32 days after planting. Differences in growth rate and N uptake began about 50 to 60 days after planting. Nitrogen flux peaked just before tasseling (V10 stage) and decreased for about 20 days before the growth rate resumed (R1 growth stage).

Nitrogen uptake and flux rates (Figures 6 and 7) resembled the growth rates for all treatments. Although growth rates decreased just prior to tasseling, the N flux fell below zero for WI and N1 plots. This is apparently not due to a lack of uptake, but to volatilization of ammonia from the plant during this stage of growth. Maximum N uptake was about 135 lbs/acre for the N3 treatment where 245 lbs/a were applied. Maximum flux was about 4 lbs/acre per day for the same treatment, which occurred at the V10 stage. Nitrogen uptake was nearly completed by the VT stage in N1 and N2 plots. Some increase in N content in plants grown at the highest N rate was measured between the R1 stage and final harvest. This confirms the findings reported from 1987 and 1988 research (Stroehlein et al, 1988 and Doerge et al, 1989). This pattern of seasonal N uptake differs 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 highest water plots (Water Level III) which is in contrast to previous findings. In 1988 slightly higher accumulations were measured in the low water plots (WI) at the end of the season. This reversal is probably the result of greater N recovery in WIII plots due to precise daily irrigations, splitting N application into five application dates versus four in 1988 and a slight delay in making the final N application in 1989. Nonetheless, differences in water rate had much less effect on total N accumulation by sweet corn than did differences in N supply.

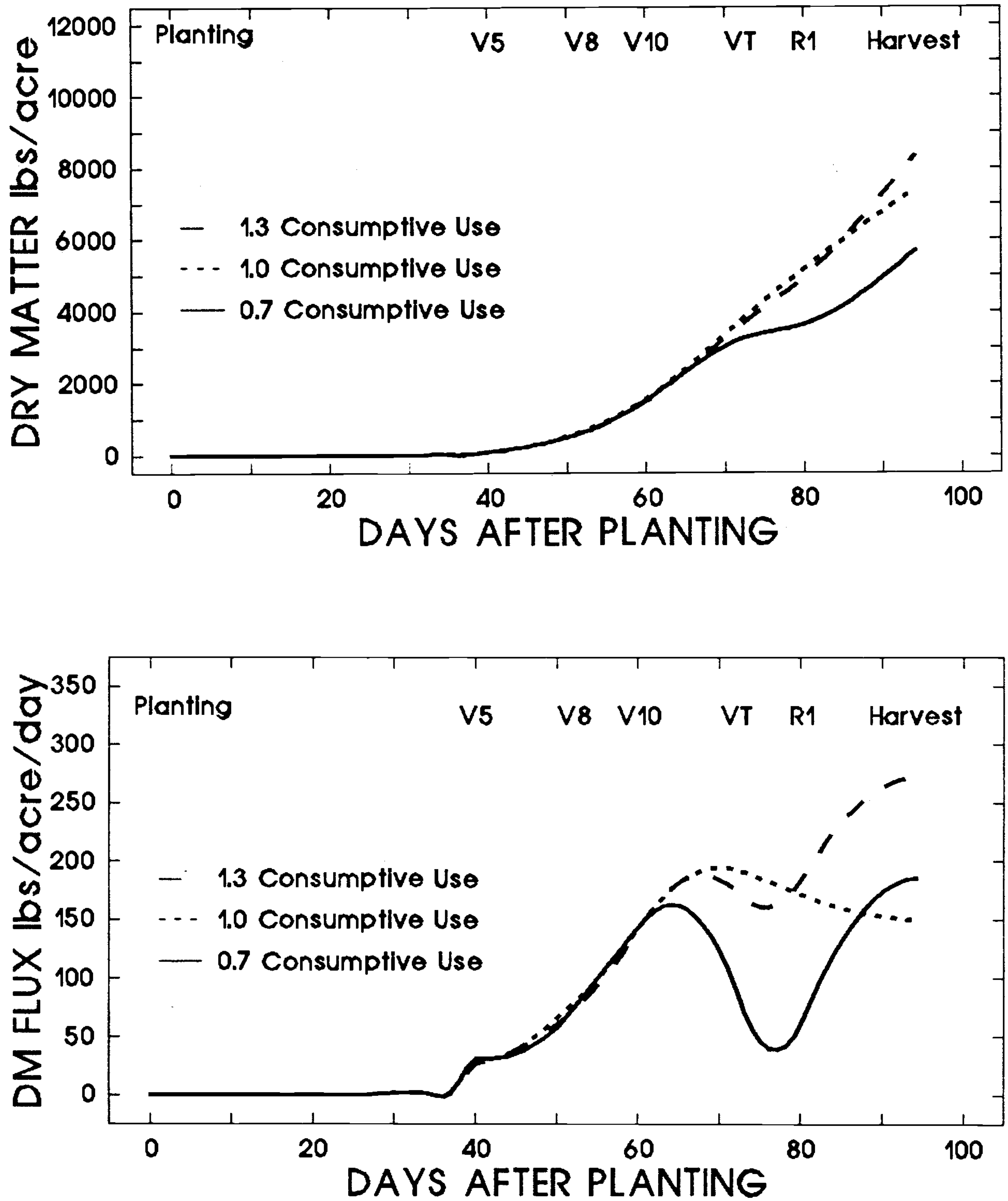


Figure 4. Dry matter production and daily flux rates in 'Sweetie '82' sweet corn as affected by water rates.

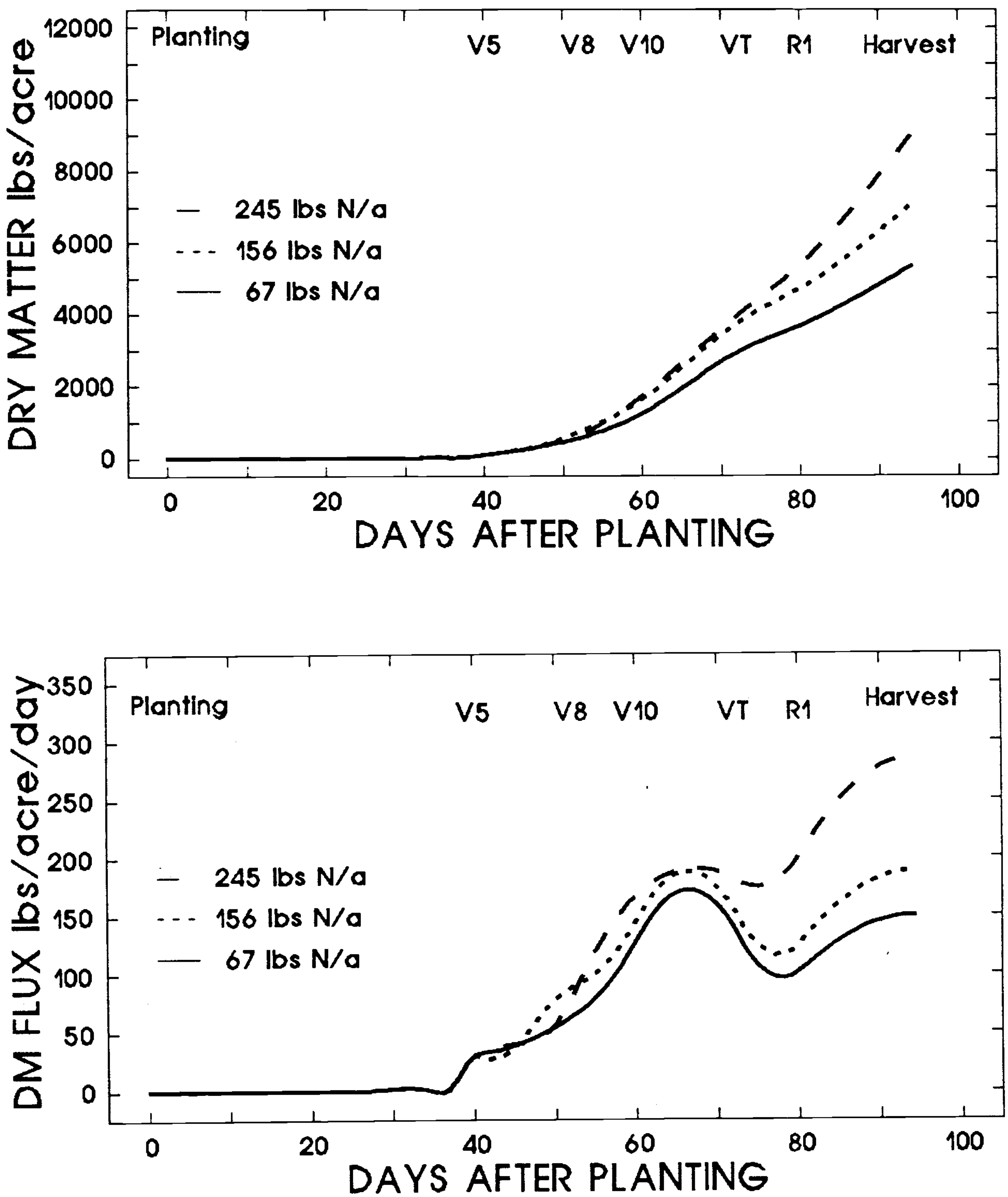
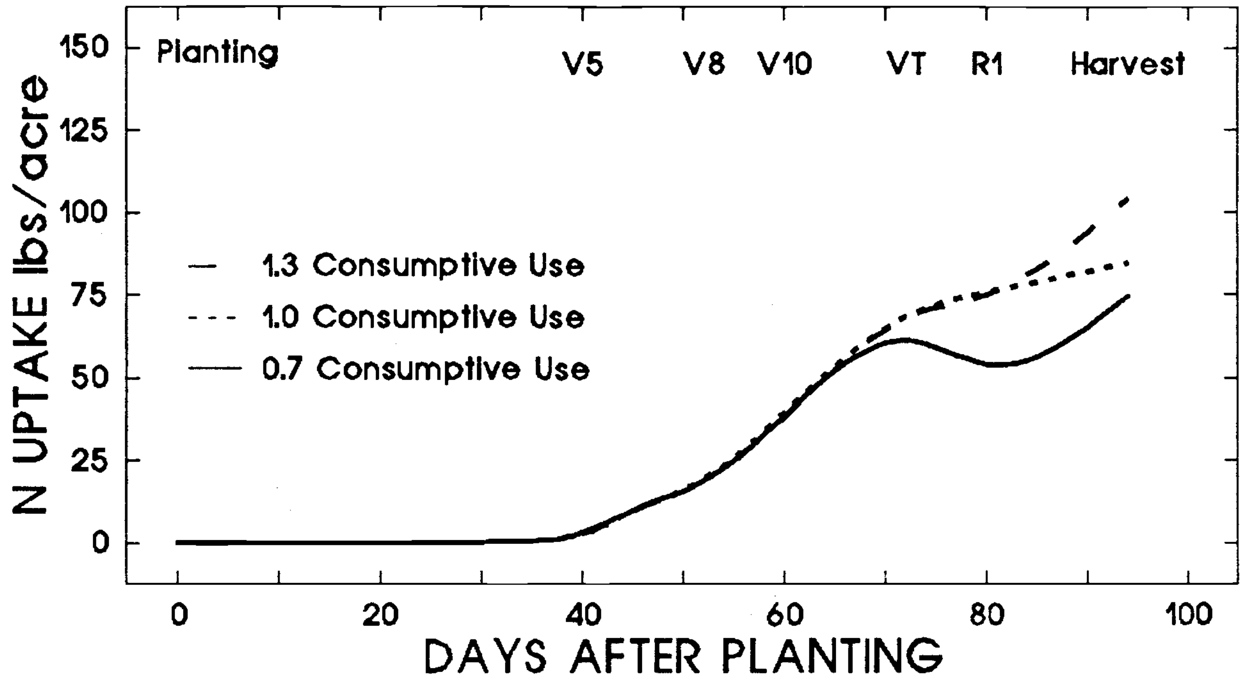


Figure 5. Dry matter production and daily flux rates in 'Sweetie '82' sweet corn as affected by nitrogen fertilizer rates.



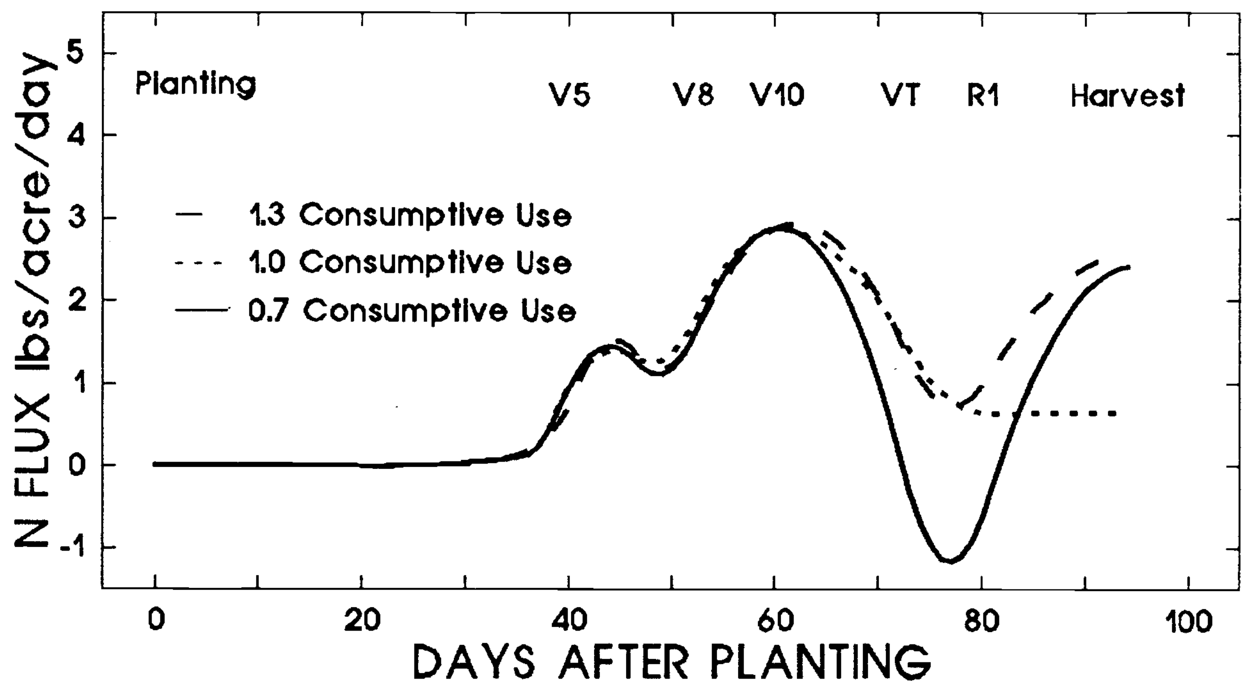


Figure 6. Nitrogen uptake and daily N flux rates in 'Sweetie '82' sweet corn as affected by water rates.

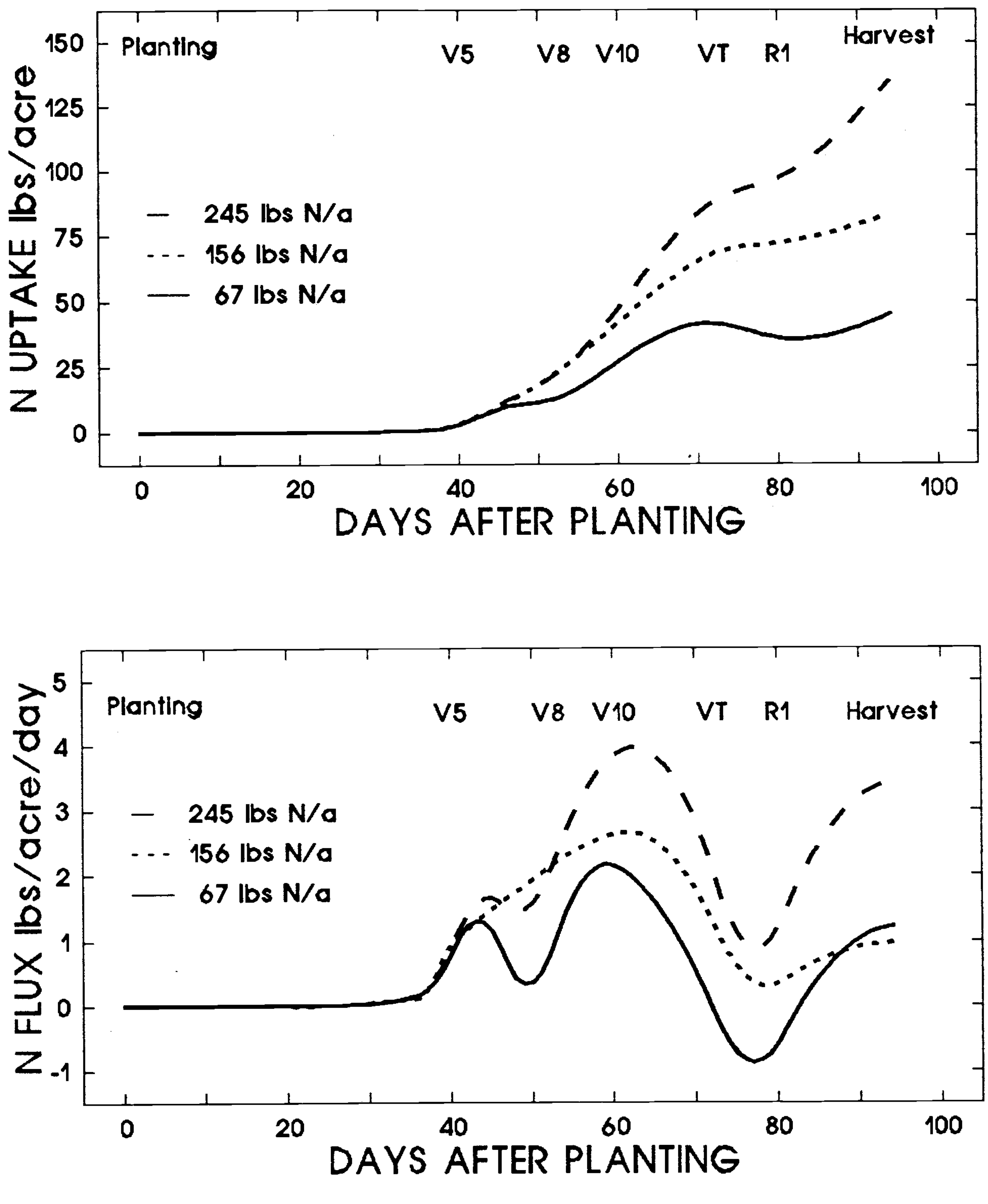


Figure 7. Nitrogen uptake and daily N flux rates in 'Sweetie '82' sweet corn as affected by nitrogen fertilizer rates.

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