Subsurface Drip Irrigation and Fertigation

Using phosphorus and potassium nitrate to increase yield and quality of processing tomatoes.

by
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Overview

Dr. Claude J. Phene (a soil and irrigation scientist, formerly Director of the USDA-ARS, Water Management Research Laboratory in Fresno, California and a longtime proponent of fertigation with Microirrigation) demonstrated with his former staff, that precise fertigation techniques based on plant uptake of nutrients could greatly improve the yield, quality and water use efficiency of the processing tomato. Similar research and yields were duplicated in Israel in cooperation with colleague Dr. Beni Bar Yosef of the Volcani Institute.

Site Information

A four year scientific study comparing surface drip with subsurface drip irrigation (SDI) was conducted near Five Points, California from 1987 to 1990. This study showed that precise fertigation techniques, based on plant uptake of nutrients, could greatly improve the yield, quality and water use efficiency of the processing tomato.

The research site was located on a 1.6 ha of a deep soil from the Panoche Clay Loam series; this soil allows the tomato root development and water and fertilizer extraction down to 2 m. The water used to irrigate this experiment came from the California Aqueduct. The water was applied through a conventional drip irrigation system, installed on top and in the middle of the 1.5 m wide beds and through a SDI system with laterals buried at 0.45 m depth in the middle of each bed. The drip irrigation laterals consisted of in-line, turbulent flow emitters, spaced 1 m apart and with a nominal discharge rate of 4 liters per hour.

Methodology

The replicated experiment consisted of:

- 40 beds
- 100 m in length
- 1.5 m wide
- two rows of processing tomatoes (UC-82B Var.) seeded on each bed, approximately 0.5 m apart
- each drip line supplied water and nutrients to two rows of tomatoes

The irrigation system was controlled automatically by a computerized controller using real time evapotranspiration measurements from a precision weighing lysimeter. The lysimeter continuously measured water used by the plants and used this information in a feedback loop; the controller determined hourly when and how much to irrigate. At the peak seasonal water use, the high frequency system irrigated as many as 10 times a day. The accuracy of this irrigation scheduling method has been well documented and is capable of eliminating most plant water, nutrient and net photosynthesis stresses. ***Results from several previous research projects have demonstrated that it is necessary to first eliminate crop water stress in order to be able to determine true fertigation responses and produce high crop yields.***

At seeding time, a N and P commercial fertilizer (11-48-0) was applied directly 50 mm below the seed at a rate of 110 kg/ha. All the remaining fertilizers were injected throughout the season with a flow-sensing, proportioning pump, adjusted weekly to maintain nutrient concentrations within adequate ranges and

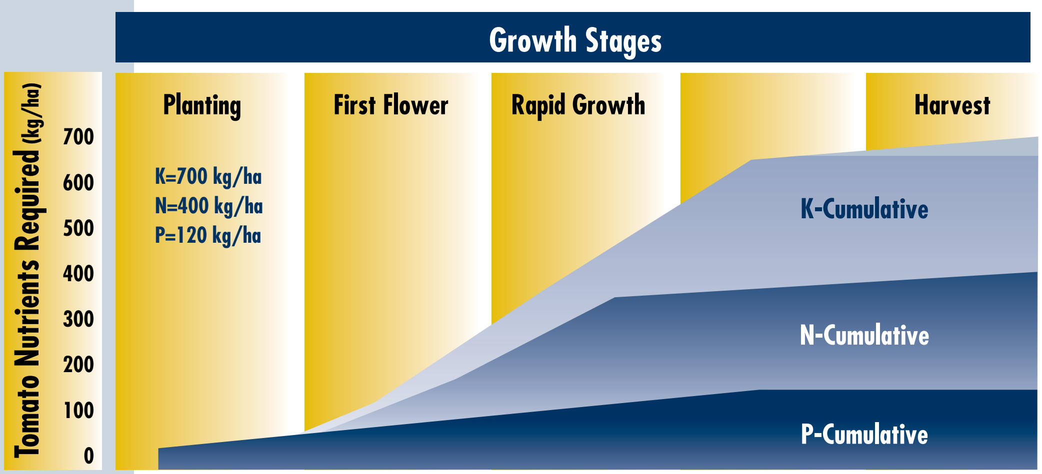

FIGURE 1 *Nitrogen phosphorus and potassium requirements for processing tomatos irrigated with subsurface drip irrigation and expected to produce a marketable yield 175 ton/ha.*

based on nutrient levels obtained from weekly tissue analyses. The *N, P,* and *K,* applied are shown in *Table 1* for each treatment, respectively. These rates were based on previously determined N, P, and K requirements to produce 175 ton/ha. of processing tomatoes, grown at the same site under similar irrigated conditions *(Figure .1).*

The main N source was calcium-ammonium nitrate (17% N) and it was injected at the beginning of the season. Potassium nitrate (13% N) was the other N source and it was injected during fruit formation and maturation when the plant requirement for potassium is large and the plant uptake rate of K is rapid. The fertilizer injection schedule for processing tomato was based on a schedule shown in ***Table 2*** *(on reverse side of this page)*. This schedule was formulated based on nutrient uptake for the processing tomato grown in a clay loam soil. This schedule was supplemented by a weekly petiole (tissue) analyses and adjusted as needed to maintain the concentration of NO_3-N, PO_4-P and K within the ranges established for these nutrients in previous experiments. In this case study, we will only report on results from the SDI portion of the study.

Since the late 1980s, several tomato growers have adopted some simplified versions of the SDI/fertigation techniques described here and many of them have doubled their tomato yields. In this study, the recommended fertilizer rates were not fully applied, mostly because the clay loam soil used was able to supply a significant portion of these nutrients; however, seasonal N-P-K uptake values for above ground plant dry matter were close to the seasonal amount of fertilizer per 5 ton of harvested tomato, recommended in ***Table 2.***

TABLE 1 *Effect of N-P-K fertigation on marketable yields, yield per unit of nitrogen applied and gross return of subsurface drip irrigated processing tomato.*

Treatment Number	Fertilizer at Seeding / N (kg/ha)	Fertilizer at Seeding / P_2O_5 (kg/ha)	Fertilizer Applied via Fertigation / N (kg/ha)	Fertilizer Applied via Fertigation / P_2O_5 (kg/ha)	Fertilizer Applied via Fertigation / K_2O (kg/ha)	Marketable Yield (ton/ha)	Yield N-Applied* (kg/kg)	Gross Return** ($/ha)
1	12	56	151	0	0	121	742	6665
2	12	56	270	209	0	167	592	9198
3	12	56	302	0	433	185	589	10,190
4	12	56	302	152	433	220	701	12,118
5	12	56	302	304	433	213	678	11,732

**Yield of marketable tomato/unit of nitrogen applied (kg/kg).*
***Gross return based on a price of $55.08 per metric ton.*

Results

Yields - The recent California State average machine harvested yield for processing tomatoes varies from year to year from 70 to 80 ton/ha. For research purposes, the tomatoes in this study were both manually and machine harvested but because the tomato harvester was not designed for such a high yield, about 20% of the marketable tomatoes were lost and the results reported here are from hand harvest of all tomatoes, in twice-replicated 6 m section of beds.

In this study, marketable yields ranged from 120 ton/ha for treatment #1 to 220 ton/ha for Treatment #4. Regardless, the relative effect of N-P-K fertigation on marketable yield of processing tomato irrigated by SDI is clearly demonstrated.

Since all the SDI treatments were randomly replicated and irrigated with the same accuracy, the yield increase from 121 to 220 ton/ha resulted mostly from N-P-K fertigation at the rates shown. Based on an average price of $55.08/metric ton, the gross return increased from $6,665 to $12, 118/ha.

Quality - The tomato quality data presented in ***Table 3*** *(on reverse side of this page)* shows the fertigation responses of single fruit weight, percentages of culls and large green tomatoes and the soluble solids of the five treatments listed in ***Table 1.***

- The single fruit weight increased 13% from 60.4 g. for treatment #1 to 68.3 g for treatment #5.
- The cull percentage decreased 57.8 and 39.4% from a high of 3.3% (treatments #2 and 5) to lows of 1.4 and 2.0% for treatments 3 and 4, respectively.
- The large green tomato percentage decreased 51.1% from a high of 5.97% (treatment #5) to a low of 2.29% in treatment #4.
- The high percentage of large green tomatoes in treatment #5 could have resulted from a nutrient imbalance generated by excessive phosphoric acid injection which kept the tomatoes from maturing.
- The soluble solids is an important quality factor since many tomato processors specify their desired soluble solids level and even pay a premium for high solids.

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- Soluble solids for the UC-82B variety typically range from 4.4 to 5.5 °BRIX. Here, the solids range from a low of 4.65 (treatment #2) to a high of 4.81 °BRIX (treatment #4). Previous experiments have shown that soluble solids of subsurface drip irrigated UC-82B tomato can be increased by managing fertility and imposing a slowly increasing water stress during the fruit maturation stage.

Conclusions

Results demonstrate that accurate management of water and fertilizers with SDI systems is the next step in producing extremely high yield of high quality processing tomatoes and therefore high gross and net returns. Similar high yields have also been obtained with sweet corn, cantaloupes, broccoli, cotton, alfalfa, grape and nut trees.

Emphasis on the fertilizer application rate, source, timing and nutrient balance is also critical for achieving these results. This is especially true with macro-nutrients like P and K and minor elements like zinc and iron which can be absorbed in the soil and may not be readily available for rapid plant uptake.

For crops which are salt sensitive (especially chlorides) and in areas were salinity is a problem and groundwater is susceptible to contamination, the use of potassium nitrate is extremely advantageous since both accurately supplied K and NO_3-N are taken up by the crop as it is applied and there is no residual salts left in the soil at the end of the season. In addition to the improved crop yield and quality, SDI has been shown to greatly improve water use efficiency (WUE is usually defined as the yield per unit of water use or water applied). Improving WUE is critical in arid and semi arid areas of the world where the water supplies are limited and the populations are increasing rapidly.

TABLE 2 *Fertigation recommendations for subsurface drip irrigated processing tomato in a clay loam soil.*

Growth Stages	Number of Weeks	N (kg/ha/week/ 5 tons of projected harvested tomato**)	P_2O_5 (kg/ha/week/ 5 tons of projected harvested tomato**)	K_2O* (kg/ha/week/ 5 tons of projected harvested tomato**)
At Seeding*** (kg/ha)	-	12.0	60.0	0
First Flower (10%)	8	0.14	0.11	0.17
Rapid Growth	6	0.47	0.11	0.56
Full Bloom	7	0.24	0.11	0.48
Mature/ Harvest	3	0	0.11	0.22
Seasonal Weight of Fertilizer Applied per 5 Tons of Harvested Tomato (kg/ha/5 ton of tomato)		5.62	2.64	8.74

**Apply as potassium nitrate only.*
***Concentration (rates) of N, P and K should be adjusted weekly, based on concentrations of recently matured plants.*
****Not included in the weekly totals.*

TABLE 3 *Effect of N-P-K fertigation on some quality parameters of subsurface drip irrigated processing tomato.*

Treatment Number	Single Fruit Weight* (g)	Percentage of Culls** (%)	Percentage of Large Green** (%)	Soluble Solid*** (°brix)
1	60.4	3.2	3.78	4.68
2	61.2	3.3	3.47	4.65
3	63.3	1.4	3.20	4.77
4	68.3	2.0	2.92	4.80
5	66.9	3.3	5.97	4.70

**Determined from the average 250 random picked marketable tomatos.*
***Percentage of total weight of harvested tomatos.*
****Measured with a refractometer and blended juice from 6-8 tomatos.*

UNIT CONVERSION TABLE

TO CONVERT	INTO	MULTIPLY BY
Hectare (ha)	Acre (a)	2.471
Meter (m)	Feet (ft)	3.281
Meter (m)	Inch (in)	39.37
Millimeter (mm)	Inch (in)	0.03937
Kilogram per Hectare (kg/ha)	Pound per Acre (lb/ac)	0.89286
Kilogram per Square Centimeter (kg/cm^2)	Pound per Square Inch (lb/in^2)	14.22
Gram (g)	Pound (lb)	2.205×10^3
Ton (metric) (t)	Pound (lb)	2,205
Ton / Hectare (t/ha)	Ton (short) / Acre (t/ac)	0.446175
Liter (L)	Gallon (g)	0.2642
Liter per Minute (L/min)	Gallon per Minute (gpm)	0.2642

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