# HIGH-FREQUENCY TRICKLE IRRIGATION AND FERTILIZATION OF POTATOES, SWEET CORN AND TOBACCO SEEDBEDS[1]

by

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## INTRODUCTION

Problems of normal irrigation management in the semi-Arid West (12) are aggravated in the Southeast where rainfall is frequently erratic. If the soil water storage is exceeded, heavy rainfall leaches soluble nutrients stored in the root zone to lower soil depths (8,9) and may cause deficient aeration. Nitrate-nitrogen ($NO_3$-N) movement in the soil and uptake by plants in these sandy soils is highly dependent on unpredictable excesses and shortages of rainfall and irrigation methods. The greatest potential for volatilization and $NO_3$ leaching occurs when cultivated sandy soils receive heavy rainfall after irrigation (10).

The high-frequency irrigation concept (several short irrigations each day) was tested with trickle irrigation systems to determine its effectiveness with various crops grown on sandy soil in humid regions. Trickle irrigation is a method by which water is applied slowly to soil through mechanical devices (called emitters) located along the lateral or porous plastic tube, from which water, under low pressure, slowly seeps. Daily doses of small amounts of soluble nutrients can be injected with trickle irrigation water to increase nitrogen (N)-use efficiency, reduce soil $NO_3$ leaching and produce optimum yield with lower fertilizer rates.

The objectives of this paper are to briefly describe the design of high-frequency trickle irrigation systems, discuss irrigation control and nutrient fertilization methods, and evaluate the influence of trickle irrigation and fertilization on growth of tobacco seedlings (*Nicotiana tabacum L.*) and yields of potatoes (*Solanum tuberosum L.*) and sweet corn (*Zea mays L.*).

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A schematic of a typical installation of Viaflow trickle irrigation system is shown in Figure 1. The system consists of a well and pump operated by either an electrical- or gasoline-powered motor. A chemical feeding system may be connected to the intake side of the pump to inject soluble fertilizers, insecticides, herbicides, and, if needed, water treatment chemicals, like chlorine or wetting agents. The chemical feeding rate can be adjusted by flow-control valves or by using orifices designed for specific flow rates. Water and chemical solutions should be filtered through a sand and/or cartridge filter to remove impurities before injection into the Viaflo tubing. The main supply lines conduct the water to the manifold, and the pressure is regulated at the manifold by pressure-regulating valves and stand pipes or by flow-control valves, which deliver the same amount of water for a given range of pressures. Manifolds can be polyethylene, PVC, or rubberized-nylon reinforced tubing (layflat hose). Black polyethylene feeder lines are inserted into punched or drilled 0.83-cm diameter (21/64 in)holes. Because low pressure is maintained in the manifold, feeder lines can be inserted into the manifold without connectors or gaskets. Connector cones supplied with the system connect the Viaflo tubing to the feeder line. Dead ends of Viaflo tubing lines are usually capped with connector cones or simply tied into tight knots.

Cross-sectional schematics of the soil profile, row spacings, and position of the trickle irrigation tubing and soil water measuring instruments for potatoes are shown in Fig. 2 and 3 (16). The twin-row wide-bed spacing (Fig. 3 ) is advantageous because only 60% as much tubing as normal spacing is required, and it minimizes soil compaction of the crop root zone by implement traffic. This row spacing has been used successfully for sweet corn, bell peppers, and potatoes. For seedbed culture, where high density plants are growing rapidly, tubes are usually spaced 50-60 cm apart to distribute water uniformly within the bed.

## Automatic Irrigation Control System

The automatic irrigation system can be controlled by devices, like feedback electronic soil matric potential sensors (11) (Watertech, Model #1002C, Soil Moisture Sensor or Module 4005C, Route 1, Box 185-A1, Trinity, NC 27370), by electronic pan evaporation measurement devices (13), by electrically controlled tensiometers (14),by logic systems, including combination of these units which can provide an electrical contact closure (15), and/or by electrically or hydraulically operated flow-meters or valves which apply water for a predetermined amount of time or volume (10).

Automating a trickle-irrigation system is relatively easier than many other irrigation methods, because water discharge rates are lower per unit area of soil; system and well are installed permanently using smaller pipes and pumps; it minimizes interference with farming operations or agronomic practices; and its efficiency seems not to be affected by wind or radiant energy.

The automated system effectively controls amount and frequency of water application, resulting in improved water-use efficiency and yields. After the system is installed, labor, transport, and operation costs of trickle-irrigation systems are considerably lower than that of other systems (10).

## Fertilization

Fertilizing crops by applying soluble fertilizers in the water with trickle irrigation is easily accomplished as an integral part of high-frequency trickle management systems and supplies adequate nutrients to the root zone of crops (10, 12, 14, 15, 16). High-frequency application of fertilizer solutions at low concentrations to satisfy crop requirement during the growing season results in higher nutrient-uptake efficiency, a more uniform level of nutrients in the root zone, and lower fertilizer losses in humid areas (14, 15, 16). "Trickle fertilization" offers a breakthrough in plant nutrition with greater potential for substantial yield increases.

Fertilizers distributed by the trickle irrigation systems should be completely soluble to avoid precipitation and/or clogging of the Viaflo tubes. Many phosphorous (P) compounds are not satisfactory because of their poor solubility and their tendency to precipitate; therefore, it may be advantageous to apply P when the land is being prepared for planting. However, phosphoric acid and polyphosphate compounds are soluble and may be applied through trickle irrigation. Solutions containing all required nutrients are commercially available for application with trickle irrigation systems.

## TRICKLE IRRIGATION OF POTATOES

A field experiment was conducted at Florence, S.C., comparing the yield of potatoes grown on a shallow-layered Norfolk sandy loam soil (Typic Paleudult) (2, 16). Treatments were: (a) 100-cm row spacing with high-frequency trickle irrigation (CSI) Fig. 2 ); (b) twin-row spacing with high-frequency trickle irrigation (TRI) Fig. 3 ); and (c) 100-cm row spacing with no irrigation (CSNI). Twin rows or pairs of rows (35 cm apart) were spaced 130 cm on the TRI plots (Fig 3 ). Treatments were replicated three times. Plots were 30 m long and 6 rows wide; the two center rows were harvested for yield. Tuber pieces (CV Irish Cobbler) were planted about 25 cm apart in the row of all plots. Fertilizer (10-10-10 analysis) was broadcast at the rate of 1120 kg/ha over the entire test area. Herbicide, nematocide, and insecticide were applied as recommended by Clemson University.

Viaflo porous irrigation tubes were installed in the CSI and TRI plots. A strip of clear polyethylene plastic (0.01 cm thick and 20 cm wide) was placed over the porous tube and partially covered with soil to reduce evaporation on the TRI plots (Fig. 3 ). On the CSI plots, the porous tube was installed 5 cm to the right of the plants and 4 to 5 cm below the soil surface (Fig. 2 ).

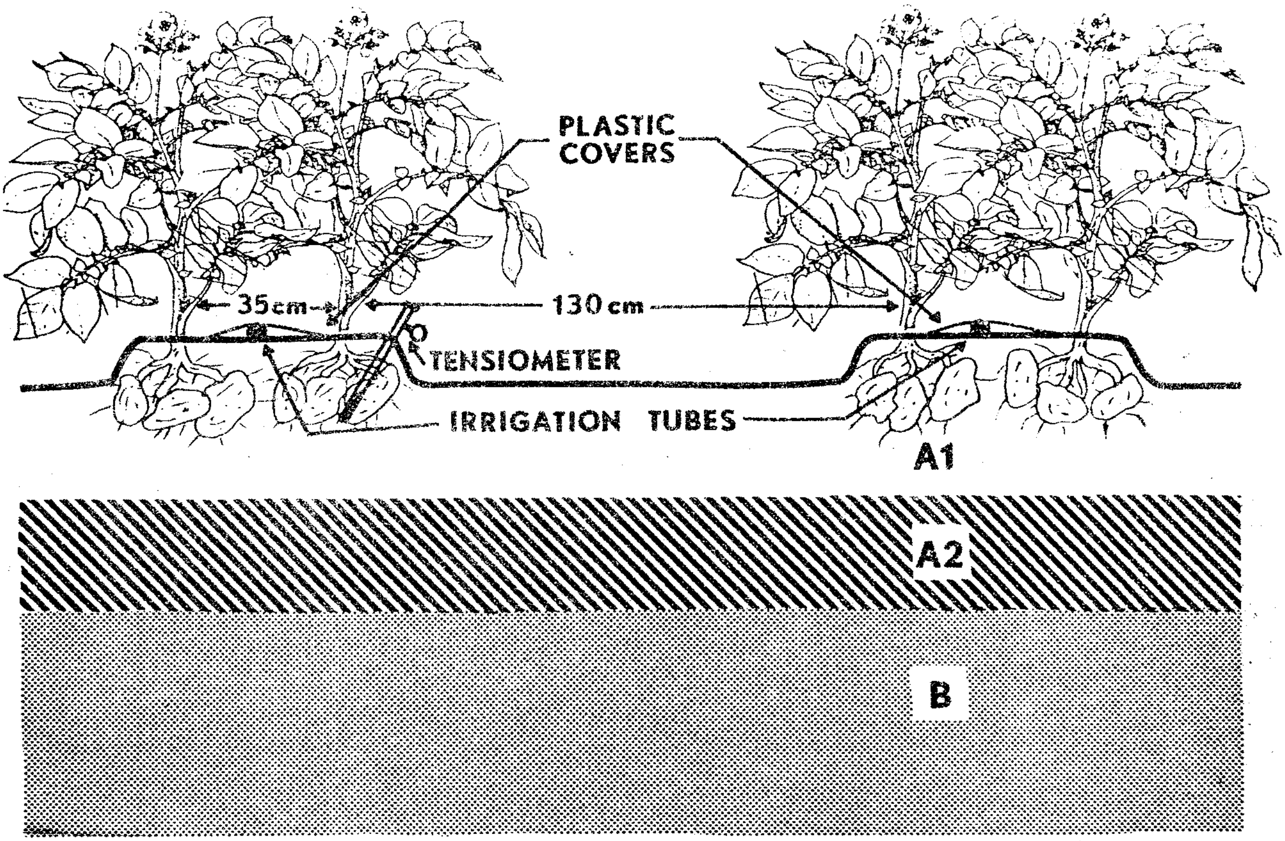

Figure 3. Schematic of soil, profile, Norfolk sandy loam (Typic Paleudult), and potatoes, trickle irrigation tube and tensiometer position.

B = TRI

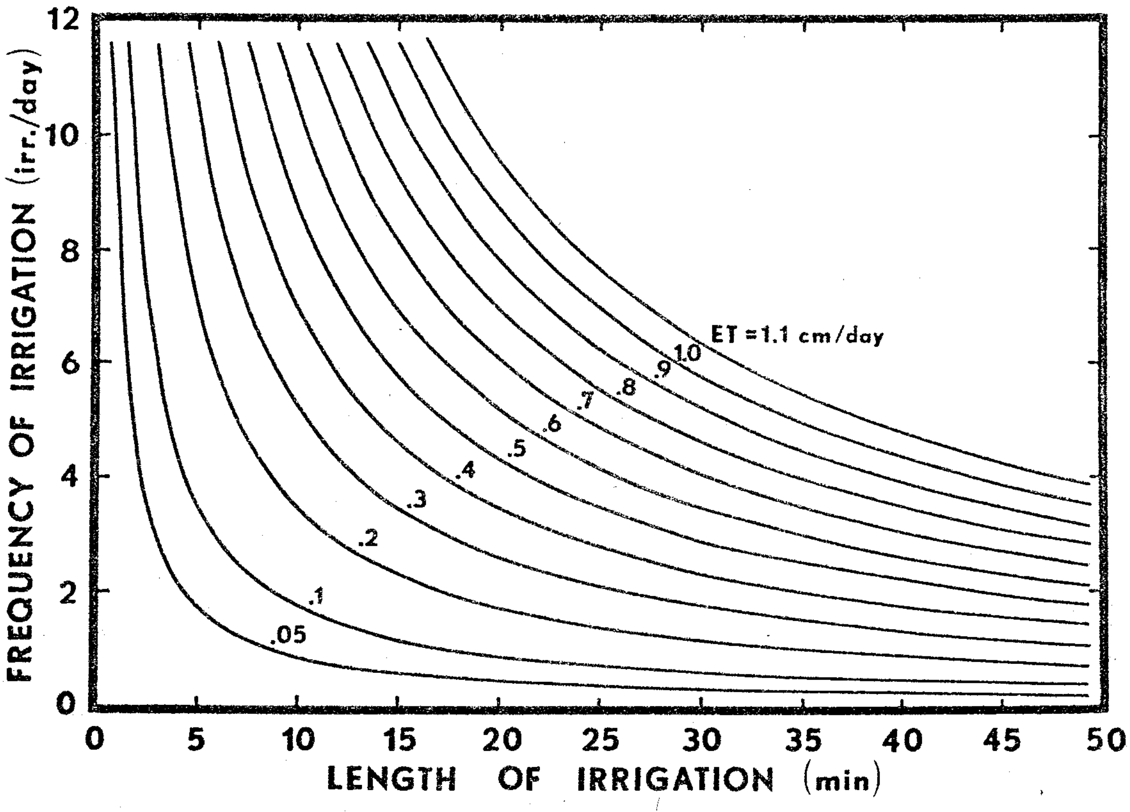

Figure 4. Irrigation frequency and time requirements for trickle irrigation system under different evapotranspiration rates.

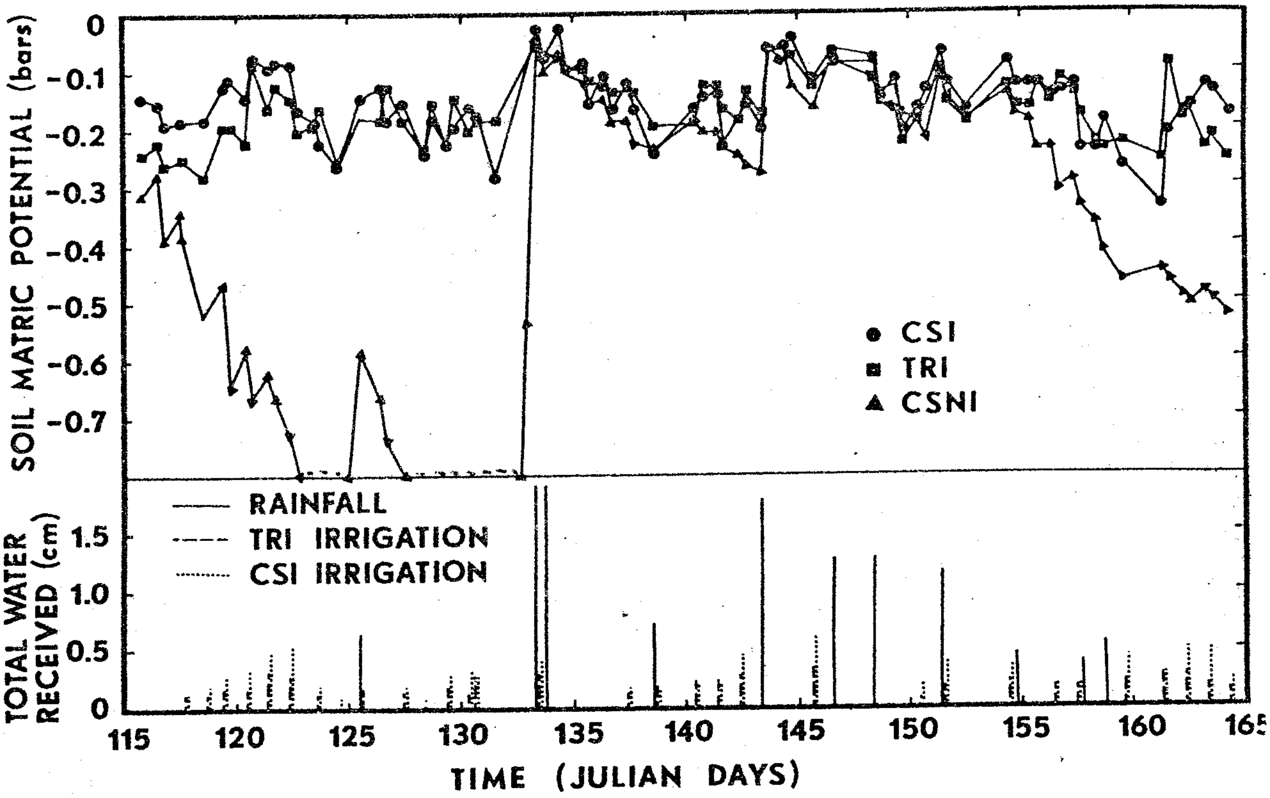

Figure . Soil matric potential 15 cm from the soil surface as influenced by three irrigation treatments, and rainfall and water application by high-frequency trickle irrigation during the 1974 growing season.

Table 2. Marketable ear weight, quality, and dry matter production for high-frequency trickle irrigated and nonirrigated conventionally spaced sweet corn for various N and K fertilization rates (1973).

| N and K fertilization rate (kg/ha) | Marketable ear weight (mt/ha) + | Number of marketable ears (ears/stalk) | Mean ear weight (g) + | Mean ear length (cm) | Pericarp (%) | Total dry matter (mt/ha) |
|---|---|---|---|---|---|---|
| 0 | 1.0 e‡ | 0.33 e | 135 d | 12.3 c | 0.99 | 3.6 d |
| 28 | 3.3 d | 0.55 d | 180 c | 13.5 b | 1.07 | 6.9 c |
| 56 | 4.4 d | 0.68 c | 170 c | 13.3 b | 0.99 | 7.8 c |
| 168 | 14.8 b | 0.90 ab | 261 a | 16.7 a | 1.01 | 11.4 a |
| 168* | 8.9 c | 0.86 b | 225 b | 14.6 b | 0.97 | 9.2 b |
| 336 | 17.2 a | 0.98 a | 262 a | 17.5 a | 0.91 a | 11.9 a |

* Nonirrigated sweet corn fertilized with 168 kg/ha of N and K.

\+ Weight includes husk.

‡ Column means followed by the same letter are not significantly different (95% confidence level).

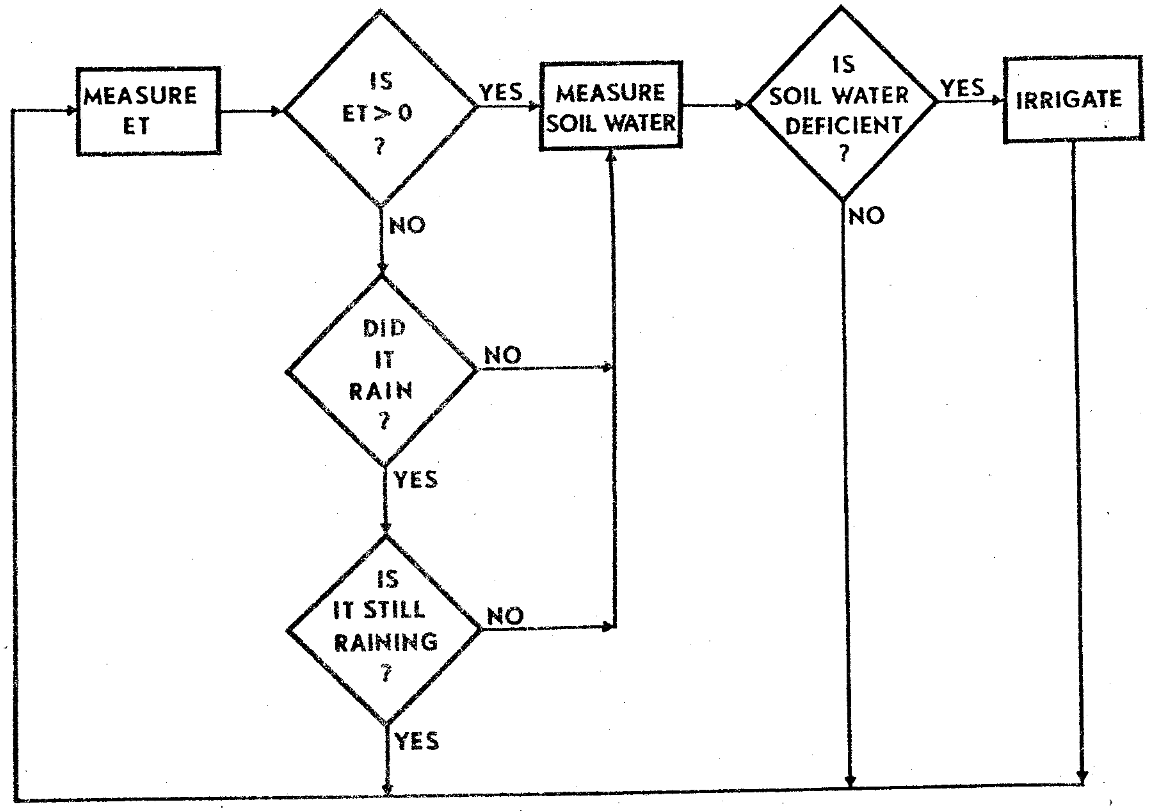

Figure 6. High-frequency irrigation control logic using a combination of standard (US Weather Bureau) automated class A pan and soil matric potential measurements.

Table 3. Tobacco seedling measurements from two irrigation methods (1975).

| | Sprinkler Irrigated | Trickler Irrigated |
|---|---|---|
| Plant height (cm) | 12.7 | 14.6 |
| Dry weight (g) | 0.290 | 0.443 |
| Number of leaves/plant | 5.1 | 5.9 |
| Leaf area ($cm^2$) | 77.7 | 107.2 |
| Seedling density<br>(plants/929 $cm^2$)<br>(plants/$ft^2$) | 47.3 | 59.6 |

Table 4. Initial cost per acre and per hectare (well not included) for trickle irrigation of tobacco seedbeds based on 1 ha (2.471 ac) using Viaflo, 5-cm diameter (2-in) well and 22 beds 90 x 4 m (295 x 13 ft) spaced 1 m (3.3 ft) apart.

| | Cost per acre | Cost per hectare |
|---|---|---|
| Pumps + motor (gasoline) 378.5 l/min (100 gal/min) | $ 121.41 | $ 300.00 |
| Filter system (6 Cuno P-10, 5 u m cartridges) | 50.99 | 126.00 |
| Pipe connections, fittings, and pressure gauge | 32.38 | 80.00 |
| 5-cm diameter (2-in) layflat hose manifold 110 m (360 ft) long | 89.03 | 220.00 |
| 0.95-cm (0.375-in) polyethylene header tube 220 m (722 ft) | 17.31 | 44.00 |
| *Viaflo, 5 tubes/bed, 22 beds/ha 10,000 m (32,810 ft) | 265.48 | 656.00 |
| (Total cost does not include well and installation) | $ 577.10 | $1426.00 |

* Yearly cost, unless tubes are salvaged.

The initial material costs per hectare (1976) (well and installation not included) for trickle irrigation of tobacco seedbeds using Viaflo porous plastic tubes are shown in Table 4. Based on 10 sprinkler irrigations/season, and 32 manhours/ha at $2.50/hr, labor saving alone would compensate for the recurring cost of the Viaflo tube and filters. Additional savings resulting from smaller energy consumption, improved fertilizer and insecticides efficiencies, and better quality seedlings represent higher net profits to the farmer.

## CONCLUSIONS

Distribution of water and nutrient solutions with the porous-tube is adaptable for high-frequency irrigation in sandy soils of Southeastern Coastal Plains. Nutrient solution can supply water and nutrients as required by the crop, thereby decreasing the need for water and nutrient storage in the root zone. Increasing soil-water storage capacity may decrease root damage from excess rainfall and poor aeration.

Although irrigation water is readily available in the southeast, pumping and delivery cost of water to the irrigation system in the field can be decreased significantly by adopting high-frequency trickle irrigation nutrient-management techniques.

Potato production in the southeast is highly dependent on soil matric potential control. High-frequency trickle irrigation with nutrient solution can increase current yields and stabilize the economic position of the farming community. Adaptation of twin row beds (TRI) for trickle irrigation will reduce by 39% the cost of porous tube needed and by 17% the amount of water used as compared with CSI; however, the 76% marketable yield increase by CSI over TRI may well offset the savings realized from the tubing and water costs.

Daily low-rate application of N and K with a high-frequency trickle irrigation system can improve nutrient-utilization efficiency of crops and reduce leaching loss of nutrients. Remedial applications of fertilizers can provide crop nutrients, regardless of weather conditions, field trafficability and/or crop maturity.

Smaller seedbeds and high-frequency trickle management systems could be used to grow various types of seedlings for intensive production of early vegetable crops, like bell peppers and tomatoes.

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## APPENDIX A

This example of design procedure is based on the Viaflo Hydraulic Design Instructions (5) and on field experience. This procedure is intended to optimize the design of a Viaflo Trickle Irrigation System for a 5-ha-wide bed, twin-row crop field, with bed spaced 1.65 m apart.

1. Calculate Irrigation System Flow Rate (Fig. A1):
   a. Number of Viaflo laterals = 76
   b. Total length of Viaflo: 76 x 400 m = 30,400
   c. System Flow Rate at 0.3 kg/cm$^2$ pressure:
   30,400 m x 0.025 l/m/min = 760 l/min.

2. Calculate Flow and Size of Manifold A, B, C and D:
   a. Calculate Flow:
   76 laterals x 100 m/lateral x 0.025 l/m/min = 190 l/min.
   b. The diameter of the manifold may be constant or may be adjusted proportionally to the flow rate. Here, each manifold is comprised of two sections approximately equal in length (Fig A2).
   c. By referring to carrying capacity and friction loss tables for thermoplastic pipes, the manifold pipe diameter can be determined for allowed pressure decreases of 0.050 ($d > 5$ cm) and 0.034 kg/cm$^2$ ($d < 5$ cm).

| Pipe Section | Length of Pipe (m) | Flow Rate (l/min) | Friction Loss (kg/cm$^2$) Pipe Diameter (6.35 cm) | Friction Loss (kg/cm$^2$) Pipe Diameter (7.63 cm) |
|---|---|---|---|---|
| 1st | 32.5 | 190.0 | 0.053 | 0.018 |
| 2nd | 30.0 | 91.2 | 0.015 | 0.005 |
| | | TOTAL | 0.068 | 0.023 |

Using 6.35-cm diameter pipe results in combined pressure losses exceeding the design value of 0.05 kg/cm$^2$ and, thus, would dictate the use of next largest pipe (7.62 cm).

3. Calculate Flow and Size of Supply Mains:

By referring to carrying capacity and friction loss tables for thermoplastic pipes, main supply-line pipe diameters can be selected for allowed pressure decrease of less than 0.7 kg/cm$^2$ when centrifugal pumps are used. Larger pressure decreases may be allowed if high pressure pumps are used.

Flow in Supply Mains are:

| Pipe Section & Location | Length of Pipe (m) | Flow Rate (l/min) | Friction Loss (kg/cm$^2$) Pipe Diameter (7.62 cm) | Friction Loss (kg/cm$^2$) Pipe Diameter (10.00 cm) |
|---|---|---|---|---|
| Between Pump & Manifold A-C | 100 | 760 | 0.79 | 0.21 |
| Between Manifolds A-C & B-D | 200 | 380 | 0.43 | 0.12 |
| | | TOTAL | 1.22 | 0.33 |

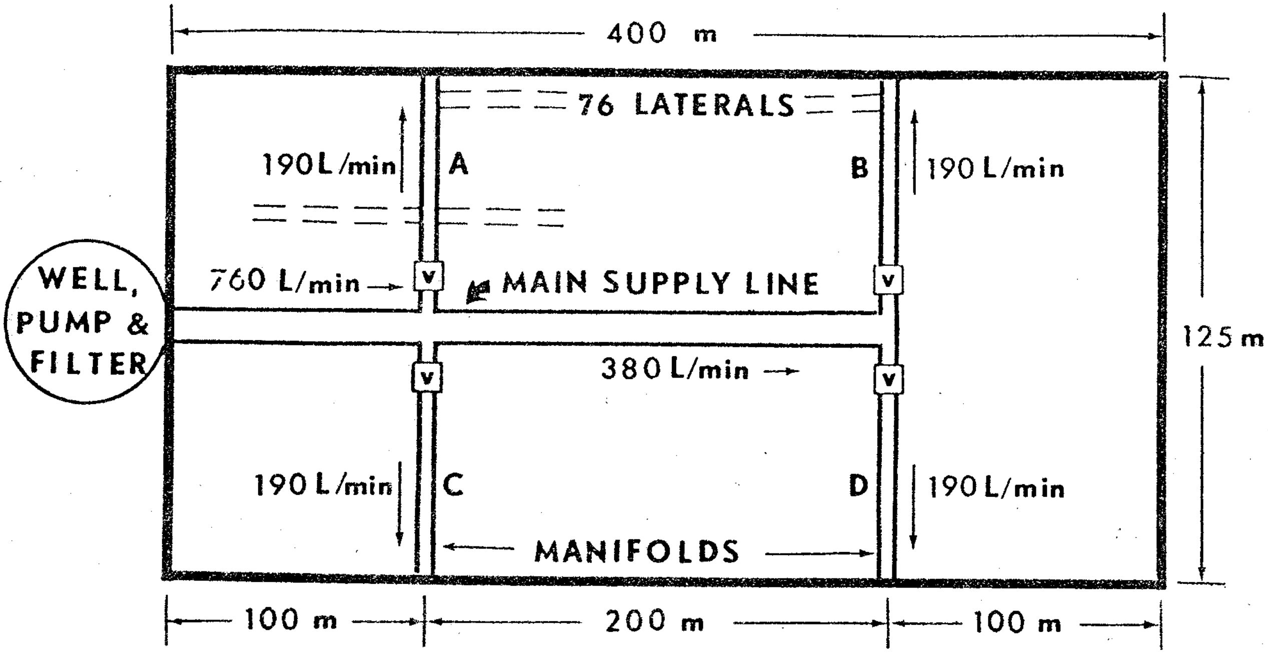

Figure A1. Hydraulic supply line layout for Viaflo Trickle Irrigation System.

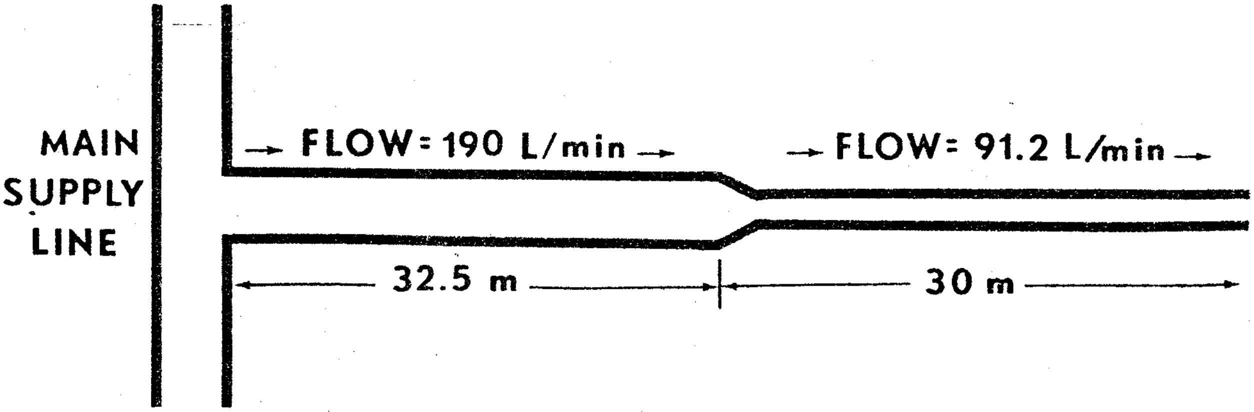

Figure A2. Manifold A, B, C and D with diameter adjusted proportionally to the flow rate required.