Limiting Quantities & Varying Frequencies. . .

Trickle Irrigation on Cotton[1]

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Introduction

Trickle or drip irrigation has been described by many as the most exciting thing to happen in irrigation for a long time. A recent survey at a trickle irrigation conference revealed that approximately 20,000 acres in California will be irrigated by this method by 1975. This enthusiastic interest has invited considerable discussion on the merits of this method.

This newer irrigation method has the capability of applying small, frequent irrigations in contrast to the customary large, infrequent irrigations by conventional methods. A series of low discharging emitters, fitted in a plastic pipe, deliver water on the soil surface to the plant. Several possible advantages of trickle irrigation over other irrigation methods have been claimed, including increased yield, higher plant quality, decreased water usage, increased fertilizer efficiency, and reduced labor costs (as summarized by Cole, 1971, and McNamara, 1970.) These potential advantages, however, have not been entirely proven.

Early reports of field trials in Israel (Goldberg and Schmueli, 1970) showed marked increases in vegetable crop yields with trickle irrigation, often double or more that obtained with sprinkler or furrow irrigation. Evaluation of early reports may have been complicated because fertilizer was given with the irrigation water at every trickle irrigation application during the main season of vegetative growth, and not given with the other methods, and because equal amounts of water were applied for all methods. Nevertheless, the more frequent trickle irrigation was of particular importance under conditions of sandy soils and saline water.

The objective of this field investigation on cotton was to evaluate the effects of limiting quantities and varying frequencies of trickle irrigation for maximum crop producton. Cotton was not chosen because it would be economical to produce under trickle, but because it is a crop which is an excellent "indicator" of moisture stress. Only one year's data was gathered and analyzed because summer climatic conditions in Central Arizona show little variation between years, and because cotton production on the adjoining furrow irrigation study indicated that 1971 was a quite normal year.

Field Procedures

This study was conducted at the University of Arizona's Cotton Research Center in Phoenix, on a relatively fine-textured clay-loam soil with a previous field history of barley for one year and cotton for three years prior to barley. The total fertilizer applied during the previous year and before planting was 420 lbs per acre of urea, none thereafter. Deltapine-16

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Table 1. Available moisture for consumptive use with trickle irrigation on cotton, 1971.

Quantity of Irrigations	*Frequency of Irrigations (days)*	*Rainfall On All Plots (inches)*	*Gravity Irrigation April 6 & 10 Water Stored (inches)*	*Trickle Irrigation, May 17 thru Oct. 1 Water Applied (inches)*	*Available Moisture for Consumptive Use (inches)*	*Adjusted Quantity of Irrigations**
1.0 Consumptive use	3	2.6	6.5	34.5	43.6	1.06 Consumptive use
	6	2.6	6.5	34.7	43.8	
	12	2.6	6.5	35.0	44.1	
0.8 Consumptive use	3	2.6	6.5	27.4	36.5	0.90 Consumptive use
	6	2.6	6.5	27.4	36.5	
	12	2.6	6.5	29.0	38.1	
0.6 Consumptive use	3	2.6	6.5	20.5	29.6	0.72 Consumptive use
	6	2.6	6.5	20.4	29.5	
	12	2.6	6.5	21.8	30.9	

* *Mean of 3 frequencies;* 1.0 *consumptive use* = 41.2 *inches* (8-*year average*).

Table 2. Cotton production with trickle irrigation, 1971.*

*Adjusted Quantity of Irrigations***	*Frequency of Irrigations (days)*	*Bolls**** (no./plot)*	*Wt./Boll (gms)*	*Lint (lbs./acre)*
1.06	**3**	**1040 a**	**4.08 a**	**1460 a**
Consumptive	**6**	**1103 a**	**4.02 ab**	**1545 a**
use	**12**	**1120 a**	**3.99 abc**	**1530 a**
0.90	**3**	**1039 a**	**4.12 a**	**1485 a**
Consumptive	**6**	**1059 a**	**4.09 a**	**1500 a**
use	**12**	**1101 a**	**3.88 bc**	**1510 a**
0.72	**3**	**934 b**	**3.90 bc**	**1270 b**
Consumptive	**6**	**880 b**	**3.82 c**	**1180 b**
use	**12**	**912 b**	**3.90 bc**	**1260 b**

* *Mean, four replications.*
** *Mean of 3 frequencies; 1.0 consumptive use=41.2 inches (8-year average).*
*** *Numbers followed by the same letter are not significantly different at 0.05 level by Duncan's Multiple Range Test.*

cotton was planted on April 5; gravity irrigations were given on April 6 and 10 for germination; on May 10, plants were thinned to 20,000 per acre on the plots; and trickle irrigation treatments were conducted from May 17 to October 1. Periodic soil moisture measurements were made during the growing season, and hand-picked yield and boll-count measurements were made from 15 ft. of each of the two inside rows on two harvest dates.

A single line of Chapin's "Twin Wall"[3] hose, with an 8-inch spacing between outside emitters, was placed on each row (40 inches apart) for the 36 individual plots, 20 ft. long and 4 rows wide. This is a double-tube system where the inner tube has widely-spaced emitters discharging into an outer tube with closer-spaced emitters. The discharge was .35 gal. per hr. per 1-ft. length. A 100-mesh screen filter was used to remove particulate matter from the water, and the trickle lines were hand-cleaned whenever emitter clogging was observed. Water applications were measured for each treatment with a turbine vane, household-type water meter and were controlled by electric time clocks and solenoid valves.

Management criteria for trickle irrigation consisted of applying three quantities, based on ratios of the plant's consumptive-use estimate, at three frequencies. These nine treatment combinations were replicated four times in a split-plot design. The amount of irrigation water to be applied was determined by multiplying 1.0, 0.8, and 0.6 by the consumptive-use rate for periods of 3, 6, and 12 days. The seasonal 1.0 estimate was 41.2 inches, an 8-year average of soil-moisture measurements on a standard furrow irrigation practice at the Cotton Research Center (Erie et al., 1968). Figure 1 shows the consumptive-use curve to develop management criteria.

Consumptive use should not be confused with water requirement. Consumptive use, or evapotranspiration, includes the amount of water used in transpiration on a given area, in building of plant tissues, and in evaporation from the adjacent soil. Water requirement is the gross amount of water that must be delivered to the field. This requirement consists of consumptive use *plus* all losses, including water-application efficiency, distribution efficiency, distributon efficiency, deep percolation, and other reasons for applying additional water. In this study, water application and distribution efficiencies were nearly perfect, since trickle irrigation laterals were only 20 ft. long and water applications were individually controlled to each plot. Therefore, it was assumed possible to apply only the amount of water needed for consumptive use on the trickle irrigation plots.

Adjacent to the trickle irrigation investigation was a replicated furrow irrigation study with an identical cotton variety, plant population, and fertilization practice (Erie et al., 1972). A statistical comparison between the two methods would not be correct, since furrow treatments were not randomized within the trickle experiment. Nevertheless results from the most favorable furrow irrigation treatment can serve as a guide to the success of the trickle irrigation treatments.

[3] *Trade names and company names, when included, are for the convenience of the reader and do not imply preferential endorsement by the U.S. Department of Agriculture of a particular product or company over others.*

Table 3. Early season cotton production with trickle irrigation, 1971.*

*Adjusted Quantity of Irrigations***	*Frequency of Irrigations (days)*	*Bolls**** (No./plot)*	*Bolls*** (% of full season yield)*	*Lint (lbs/acre)*	*Lint (% of full season yield)*
1.06	**3**	**784 a**	**75.4**	**1160 a**	**79.5**
Consumptive	**6**	**740 ab**	**67.1**	**1120 a**	**72.5**
use	**12**	**783 a**	**69.9**	**1130 a**	**73.9**
0.90	**3**	**750 ab**	**72.2**	**1125 a**	**75.7**
Consumptive	**6**	**723 ab**	**68.3**	**1075 ab**	**71.7**
use	**12**	**657 bc**	**59.7**	**930 bc**	**61.6**
0.72	**3**	**644 bc**	**68.9**	**925 bc**	**72.8**
Consumptive	**6**	**548 c**	**62.3**	**755 c**	**63.9**
use	**12**	**555 c**	**60.9**	**780 c**	**61.9**

* *Mean, four replications, harvested October 10 from blossoms set by approximately August 15.*
** *Mean 3 frequencies; 1.0 consumptive use = 41.2 inches (8-year average).*
*** *Numbers followed by the same letter are not significantly different at 0.05 level by Duncan's Multiple Range Test.*

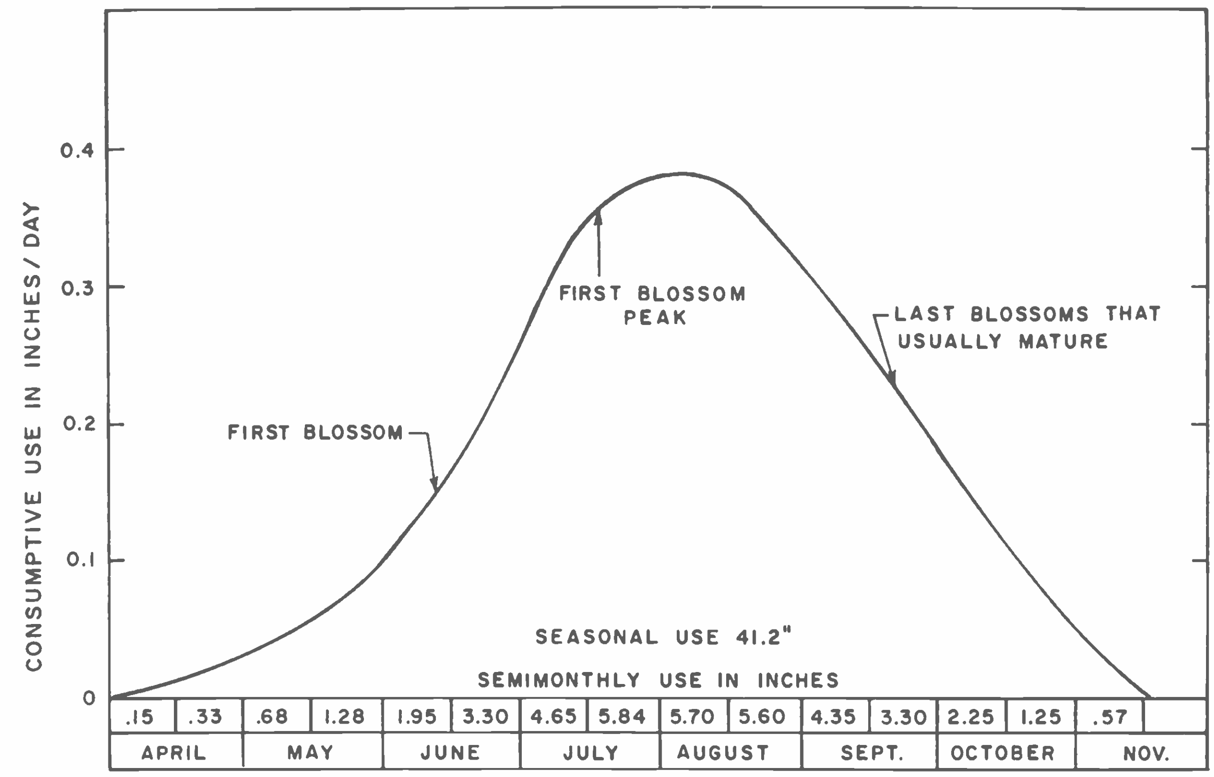

Fig. 1. Mean consumptive use for cotton used to develop management criteria for trickle irrigation, 1971.

Trickle Irrigation Results

Water applied for consumptive use including gravity irrigations for germination, trickle irrigations during the growing season, and rainfall, is listed in Table 1, resulting in adjusted 1.06, 0.90, and 0.72 ratios of the consumptive-use estimate. Before trickle irrigations were started, soil-moisture measurements showed residual stored moisture from the germination period to be 6.5 inches. Most of this residual moisture remained in the soil profile for use by plants, because the soil in this investigation has a high water-holding capacity. Total rainfall on all plots for the growing season amounted to 2.6 inches. The total number of trickle irrigations was 44, 22, and 11, respectively, for irrigation intervals of 3, 6, and 12 days. This is as much as eight times the number of irrigations used in the conventional gravity method, which is usually 5 to 8 irrigations.

Two water qualities were used in the trickle irrigations: approximately 70% with dissolved salts of 1,750 ppm, and the remainder with dissolved salts of 850 ppm. Soil salinity at the end of the experiment was below 1,500 ppm in the saturation extract for the top 4 ft. of soil for all irrigation treatments. The U. S. Salinity Laboratory's Agriculture Handbook No. 60 (1954) indicates that salinity effects on cotton at this level of soluble salts would be negligible.

Seasonal production in number of bolls per plot, weight per boll, and lint yield is shown in Table 2. Numbers of harvested cotton bolls per plot showed no significant difference between the 1.06 and 0.90 consumptive-use quantities, whereas numbers of bolls decreased 16% (sig. at the 0.01 level) at the 0.72 consumptive-use quantity, compared to the two larger quantities. Analysis of variance showed decreased boll size for the 0.72 consumptive-use quantity as compared with the two larger quantities to be significant at the 0.05 level. Lint production for the total season was not significantly different between the 1.06 and 0.90 consumptive-use quantities, but lint yield decreased 18% (sig. at the 0.01 level) for the 0.72 consumptive-use quantity. The mean yield for the 1.06 and 0.90 consumptive-use quantities was 3 bales/acre. Therefore, the soil moisture needed for high production with trickle irrigation was bracketed near present consumptive-use estimates for furrow-irrigation.

Varying frequency of irrigation for all three quantities did not statistically affect boll numbers of lint production (Table 2). Boll size, however, tended to become slightly larger with increased irrigation frequency for the two larger quantities. A possible reason for the absence of a production increase with increased frequency of irrigation would be increased evaporation. Although visual appearance showed that less than 75% of the soil surface was moistened for the 1.06 consumptive-use quantity, and less than 50% was moistened for the 0.72 consumptive-use quantity for any irrigation during the growing season, the more frequent trickle irrigations would increase the number of times at which maximum evaporation would occur. Periodic soil-moisture sampling on this high water-holding-capacity soil indicated that deep percolation was minimal, regardless of the frequency of irrigation. Thus, the cotton plant did not appear stressed by the infrequent trickle irrigations.

Short-season production shown in Table 3 is of special interest to irrigated acres governed by plow-under regulations, by long-season pink bollworm control, and by a need to conserve water. The goal of short-season production is to maximize early-maturing boll numbers and size before the cut-out period. When cotton was harvested only from bolls set approximately before August 15, total production was reduced 25%, 30%, and 34% for the 1.06, 0.90, and 0.72 quantities, respectively. Data also indicated a trend of increased production with the 3-day frequency in a short season, even though frequencies had no effect on full-season production. Number of bolls and height of plants indicated that the more frequent irrigation treatment was conducive to increased early growth of plants. This trend, however, did not suggest a definite pattern for the 6- and 12-day frequencies, and more detailed study would be required before a firm conclusion can be made.

Furrow Irrigation Results

The highest mean yield for the furrow-irrigated treatments with the same cotton variety and plant population was 3.04 bales/acre (Erie et al., 1972). This was for a treatment with 8 irrigations, given when 69% of the available moisture was depleted from the top 3 ft. of soil. Soil-moisture measurements showed the consumptive use to be 40.5 inches, or nearly the same as the consumptive-use curve used to develop criteria for the various trickle irrigation treatments (Fig. 1). The field is dead level, with

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a 250-ft. length of run, providing a potential for high water application, distribution, and storage efficiency. Although water application was not measured into individual furrows, estimated water applied, based on time of irrigations and pump discharge rate plus rainfall, was no more than 45.0 inches for the entire growing season. Therefore, distinct difference in yield or water application did not result between the furrow and trickle irrigation methods in this field situation. Where conditions are such that the furrow method would not give a high irrigation efficiency, the water requirement certainly could be reduced by using the trickle irrigation method.

Summary and Conclusions

Quantity and frequency of trickle irrigation were varied to develop management criteria for maximum cotton production and increased water-use efficiency. Trickle irrigations consisted of 1.06, 0.90, and 0.72 times the present consumptive-use estimate for furrow irrigation applied at three frequencies of 3, 6, and 12 days. Lint production for the full season was nearly the same when water was applied at 1.06 and 0.90 times and decreased 18% for the 0.72 treatment. Frequency of trickle irrigation showed no significant effect on lint production between 3, 6, and 12 days for all irrigation quantities. The mean lint production for the 1.06 and 0.90 consumptive-use quantities was 3 bales/acre, with late-season production accounting for 25% to 30% of this yield. Results suggest that the amount of soil moisture needed by the cotton plant for high production with trickle irrigation is approximately equal to the present consumptive-use estimate for furrow irrigation, and that increased frequency of trickle irrigation may not necessarily increase yields on a fine-textured soil.

Furrow irrigation of cotton on an adjoining field yielded essentially the same as the trickle irrigation and required application of about the same quantity of water. In this particular field situation, both furrow and trickle irrigation methods were efficient. However, under many field conditions where furrow irrigation would not result in a high irrigation efficiency, trickle irrigation assuredly has the potential to decrease water requirements. This, of course, will be dependent upon a properly designed, managed, and maintained, non-clogging trickle system which would give a high water application, distribution, and storage efficiency. In either case, the consumptive-use requirement by the cotton plant has not changed, regardless of the irrigation method.

To further investigate the merits and feasibility of trickle irrigation, a 3-year study using trickle irrigation for table grape producton is now underway in Central Arizona. Different quantities and frequencies of irrigation, to include daily trickle irrigations, are being tested. Advantages may be greater on a vinyard, where the spacing between plants is larger.

References

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DDT Moratorium

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other areas. Sampling in January, indicated that the Yuma residues had declined to levels of the other areas (0.035 ppm). The high September values for Yuma were also seen in 1969, and 1971. These phenominally high residues are apparently the result of climatological conditions not found in the other sampling areas.

Residues in the alfalfa soils have declined negligibly (Table 2) or not at all since the 1968 growing season. One change that has been noted is that the DDT levels are declining while DDE levels are increasing — a residue "tradeoff." Since the decline is imperceptible the suggested time required for these residues to reach one-half their present level is now estimated to be greater than 20 years, with the desert soils changing the least. The desert soils, however, are sampled only from the top 0.25 inch, and are most subject to change by wind-borne deposits, and may change rapidly in value.

The DDTR residues now found in Arizona alfalfa and soil are primarily DDE, the DDT portion slowly being converted to DDE which is declining negligibly. As suggested from past studies, problems arising from DDT in the future will be attributable to DDE, the very persistent and chemically stable metabolite of DDT.

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