

EFFECT OF SOIL MOISTURE DEPLETION ON YIELD AND WATER USE EFFICIENCY OF CHILLIES, ONIONS AND BANANAS ON THE LATOSOLS OF THE NORTH WEST DRY ZONE

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INTRODUCTION

The north west dry zone of Sri Lanka is one of the two driest regions of the country. With mean annual precipitation of 900–1500 mm and a bimodal rainfall pattern, only from mid September to mid January and during April is there more than a 75% expectancy of 150 mm rainfall in any one month (Land and Water Use Division, Department of Agriculture, 1979). The major soil group of the area is the Red and Yellow Latosols (Panabokke, 1967), of the order Alfisol (de Alwis and Pluth, 1976); these are sandy loams of low available water capacity (5 cm/m). Underlying the area is miocene limestone which has karstic features (Wijesinghe, 1975), and water bearing aquifers which offer potential for an expansion of irrigated cultivation in this sparsely populated area.

This study was concerned with evaluating for three crops, namely, chillies, onions and bananas, the effect on yield and water use efficiency of different levels of soil moisture depletion. While this study was not in itself a direct evaluation of the drip irrigation system, this method of water application was used for a maintenance of one of the soil moisture depletion levels.

Various methods of irrigation scheduling have been reported elsewhere. One approach has been to schedule water application on the basis of water budgets, derived from evapotranspiration measurements. A second has been to directly measure either the soil moisture tension with tensiometers (e.g. Taylor, 1952; Richards and Marsh, 1961) or with electrical resistance blocks (Fischbach and Sumerhalden, 1974) and to irrigate once the soil moisture tension or electrical resistance exceeds a predetermined value. The neutron probe which once calibrated can directly measure soil moisture content, (Bell, 1976) has been increasingly used under experimental conditions and was used in these studies.

MATERIALS AND METHODS

This study was carried out at Vanathavillu Agricultural Research Station, (latitude 8.2 longitude 79.5). For soil and climatic conditions see Kuruppuarachchi (1981). Three crops were selected for the study on the basis of the high cash value of the economic yield and their rooting depth.

- i. Banana, variety 'Kolikuttu', rooting to 90–105 cm depth.
- ii. Chilli, variety MI 2; rooting to 30–45 cm depth.
- iii. Onion, small red local variety, rooting to 8–12 cm depth.

Experimental Treatments

Three irrigation treatments were selected:

- i. Irrigating once the 10% soil moisture depletion level of available water capacity was reached with drip irrigation.
- ii. Irrigating once the 40% soil moisture depletion level of available water capacity was reached, by surface irrigation (by hand watered basins).
- iii. Chiefly rainfed but with supplementary irrigation once the 75% soil moisture depletion was reached in the yala dry season.

Experimental Design

Completely randomised design with an unequal number of replications as replication of the drip irrigated plots was not possible. Drip irrigated plots were only laid on the yellow latosols.

Plot Size

Banana: 20m x 24m. composed of 6 blocks, each block containing 5 plants in a row. Neutron probe access tubes were sited at the base of two banana stems and at two sites, each midway between two banana plants.

Chillies and onions: 8m x 18.5m comprising of 18 basins, each basin being 2m x 2m. Individual plant spacings for chillies were 0.6m x 0.4m and for onions 0.1m x 0.1m.

Land preparation and fertilizer applications: these followed the Department of Agriculture recommendations.

Planting Dates

Banana: 2.6.80-4.6.80

Chillies: 8.6.80-10.6.80 (yala trial)
.17.10.80-20.10.80 (maha trial)

Onion: 14.6.80-16.6.80 (yala trial)

Fertilizer

Banana: 12 kg cattle manure per plant at planting; 1/2 kg per plant of NPK in the ratio of 12:8:34 at 2 months, 6 months and 10 months.

Chillies: 12 kg of cattle manure were added to each basin at planting. NPK in the form of urea, concentrated superphosphate and muriate of potash were added at a total rate of 270 kg/ha, 300 kg/ha and 60 kg/ha respectively at the time of planting and at 2, 4 and 6 weeks thereafter.

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Onions: 12 kg of cattle manure were added to each basin at planting. At planting 24 g of urea, 58 g of conc. superphosphate and 24 g of muriate of potash were added per basin. Thereafter 12 g of urea were applied at 21 days and 42 days after planting.

Irrigation

A commercial drip irrigation system (Cameron Irrigation Company Ltd., UK) was used. For chillies and onions Biwall I irrigation tubing was used spaced at 0.6 and 0.3m respectively; for bananas 12 mm bore black polypropylene tubing was laid alongside the rows of banana with a key emitter outlet (4 l/hr discharge rate) spaced every 3m at the base of each plant.

Neutron probe calibration and operational use followed the procedures described by Bell. (1976).

All plots were treated with water similarly until plant establishment. Thereafter measured quantities of water were applied to replenish the soil from the desired level of soil moisture depletion back to field capacity. Regular neutron probe measurements were taken to monitor the depletion of soil moisture content and to ensure that irrigation restored the soil to field capacity.

Growth and yield parameters

Onions: The yield was recorded per basin, 3 months after planting.

Chillies: Red ripe chillies were harvested starting at 2 1/2 months after planting and continuing at two week intervals after that: for total pod weight, the yield from the first five picks was used.

Banana: Plant height, number of leaves and girth of the stem base were recorded at monthly intervals. Fruit yield was also collected.

Other Measurements

Soil samples were obtained at the root zone of each of the crops from all treatment plots during the yala season. Electrical conductivity (EC, m mhos/cm 25°C) of the soil samples was determined by saturation extract method in order to study the change in EC of the soil with time in each of the treatments.

The actual crop water use (ET) was computed for each treatment from neutron probe data.

RESULTS

Yields

Yields for the three crops grown on yellow latosols and irrigated under the different levels of moisture depletion are shown in Figure 1.

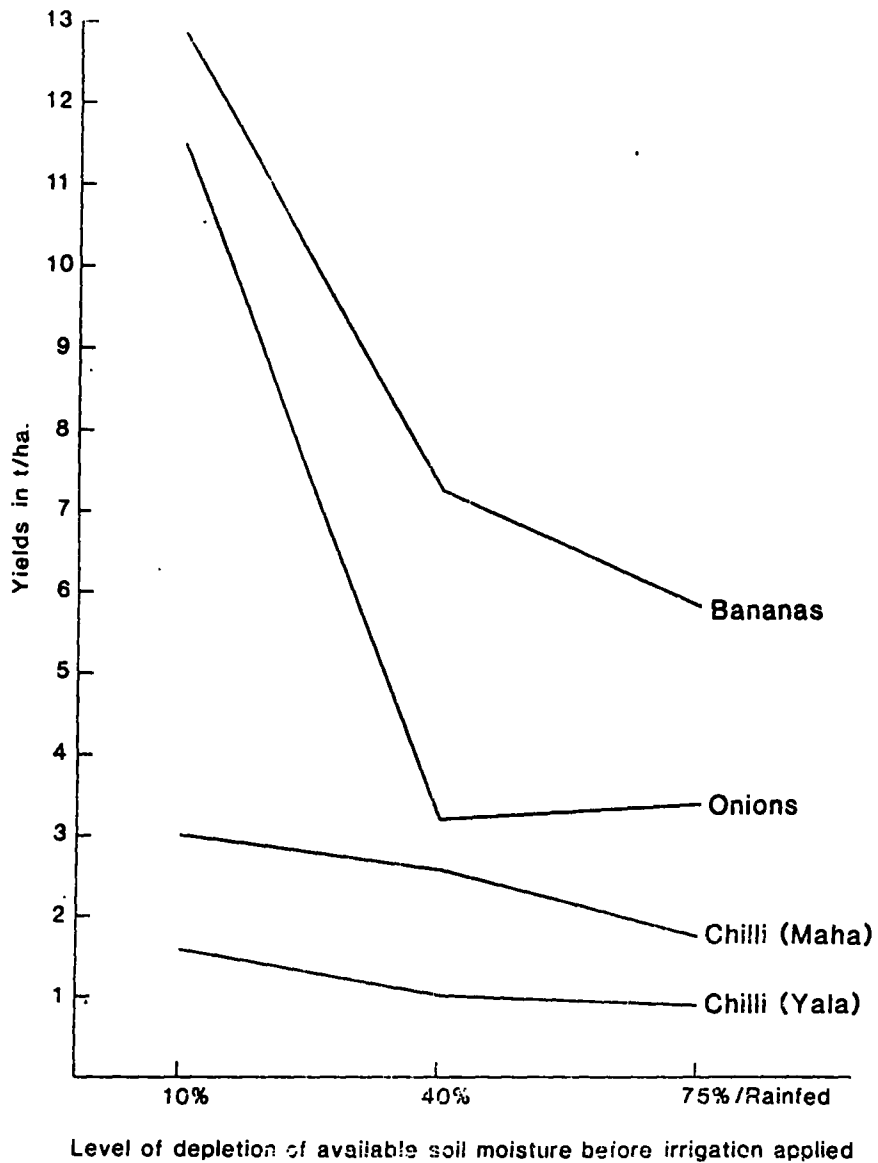


Figure 1. The yield for banana, chilli and onions grown on yellow latosols under different levels of soil moisture depletion

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Bananas irrigated by drip irrigation at 10% moisture depletion showed a significant (at 0.1 level) increase in yield of 1.76 and 2.20 times over surface irrigated at 40% depletion and rainfed plots respectively. For chillies, irrigation at 10% soil moisture depletion increased the yield for the yala crop by 1.54 and 1.64 times and for the maha crop by 1.16 and 1.77 times, over the 40% and 75% moisture depletion (rainfed for maha) treatments respectively. The effect of irrigating at 10% soil moisture depletion for onions was to increase by 2.5 times the yield over surface irrigation at 40% and 75% depletion levels but the overall yields of onions in the trials were less than the regional average for this variety. This may well have been due to physiological stress which causes tip drying as a result of high temperatures.

Surface irrigation at 40% depletion increased the yield of chillies by 1.06 and 1.52 times over the surface irrigation at 75% in yala and rainfed treatments in maha respectively. The banana yields were increased by 1.25 times in the surface irrigation trials at 40% depletion over the rainfed trials. However surface irrigated onions at 40% depletion did not show any significant yield increase over the surface irrigated onions at 75% depletion.

Increases under the drip irrigation at 10% depletion level were associated with an increased number of fruits per bunch with banana, and an increased number of bulblets per plant in onions (Table 1). In chillies the increased yields were due to the increased average weight per pod with the more frequent irrigation.

Water Use Efficiencies

The water use efficiencies (wue) in terms of harvested yield per unit volume of water applied (including both rainfall and water applied at establishment), and the harvested yield per unit of water lost by evapotranspiration (ET) were estimated for all three crops under each of the irrigation treatments (Table 2). In the latter estimate of wue allowance was made for drainage. For both methods of computation of wue and for all three crops, wue under the drip irrigation at 10% depletion was greater than wue for crops grown under the two other irrigation treatments. For onions the difference was over threefold, for chillies in the yala 1.5 times but in the maha only 1.1 times because of the rains, and for bananas two fold. The differences in wue between the 40% and 75% (rainfed in the case of maha chillies and banana) depletion treatments were small and, for example with bananas the wue expressed in kg.m^{-1} was greater for the rainfed treatment than for the 40% moisture depletion treatment.

Table 1 Effect of irrigation treatment on the yield parameters of chillies, onion and banana

		<i>*Drip irrigation at 10% depletion</i>	<i>**Surface irrigation at 40% depletion</i>	<i>Rainfed or surface irrigation at 75% depletion</i>
Banana				
Number of combs per bunch	...	7.5	6.8	6.7
Number of fruits per bunch	...	112.6	100.3	93.4
Onion				
Number of bulblets per plant	...	8.5	5.0	5.3
Chillies				
Total number of	yala	101.1	101.3	99.8
pods per plant (for the five picks)	maha	171.8	171.1	138.0
Average pod length in cm	yala	6.9	5.2	5.3

* Banana mean value of 12 blocks per treatment, each block containing 5 plants.

* Chillies and onion mean value of 2 plots each containing 18 basins per treatment.

** Banana mean value of 6 blocks per treatment, each block containing 5 plants chillies and onions: mean value of 18 basins for chillies and onions.

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The increased wue with drip irrigation at 10% depletion can be attributed to a combination of higher crop yields, a shorter crop duration (to the harvesting of the first yield) as in the case of bananas (Table 2) and a smaller quantity of water applied. There was no clear evidence to suggest that there were significant differences in drainage losses for the different irrigation treatments although examination of the neutron probe profiles does suggest that these might have been greater under the 40% and 75% irrigation treatments when water was applied less frequently but in greater quantities. Except for bananas where the crop duration under 10% soil moisture depletion was considerably less than the other two treatments, the total ET was similar for onion grown under the different irrigation treatments and this also applied to chillies.

Effect of Irrigation Treatment on Soil Salinity

The electrical conductivity (EC) of the irrigation water ranged from 2.2–2.6 m mhos cm^{-1} at 25°C during the trial period. (Class 4 or very high salinity hazard by the USDA classification (1954). However, the effect that the use of such water has on the build up of salts in the soil depends on the quantity of water applied during one irrigation and the interval between irrigations. The pattern of salt accumulation in the root zone of the three crops was monitored and these are shown in Figure 2, 3 and 4 for chillies, onions and bananas respectively. The more frequent irrigation treatments (at 10% and 40% soil moisture depletion levels) showed a more rapid increase in the soil EC of the 0–30 cm than the less frequent irrigation treatment and as demonstrated by bananas in Figure 4, this increase was in the surface layers of the soil. The rate of salt accumulation was highest with bananas and these received more water per irrigation than did the chilli and onion crops. At the end of the yala season, the highest electrical conductivities (up to an EC 13 m mhos/cm at 25°C) were found for bananas growing on the red latosols but for all banana treatments on both soil types, the onset of the first maha rains in September resulted in a dramatic drop in the soil EC (Figure 4), presumably as a result of the salts being flushed through soil, beyond the plant rooting zone. By five months after planting for the bananas, drip irrigated bananas showed their highest salt concentration at the surface layers of 0–15 cm, surface irrigated bananas at 40% depletion showed their highest salt concentration at the 15–45 cm layers and for surface irrigated bananas at 75% the highest salt concentration was found at 45–60 cm. The distribution of salt concentration according to the irrigation regime probably reflects the degree of vertical water movement, it being greatest with the least frequent irrigation interval and least under the drip system.

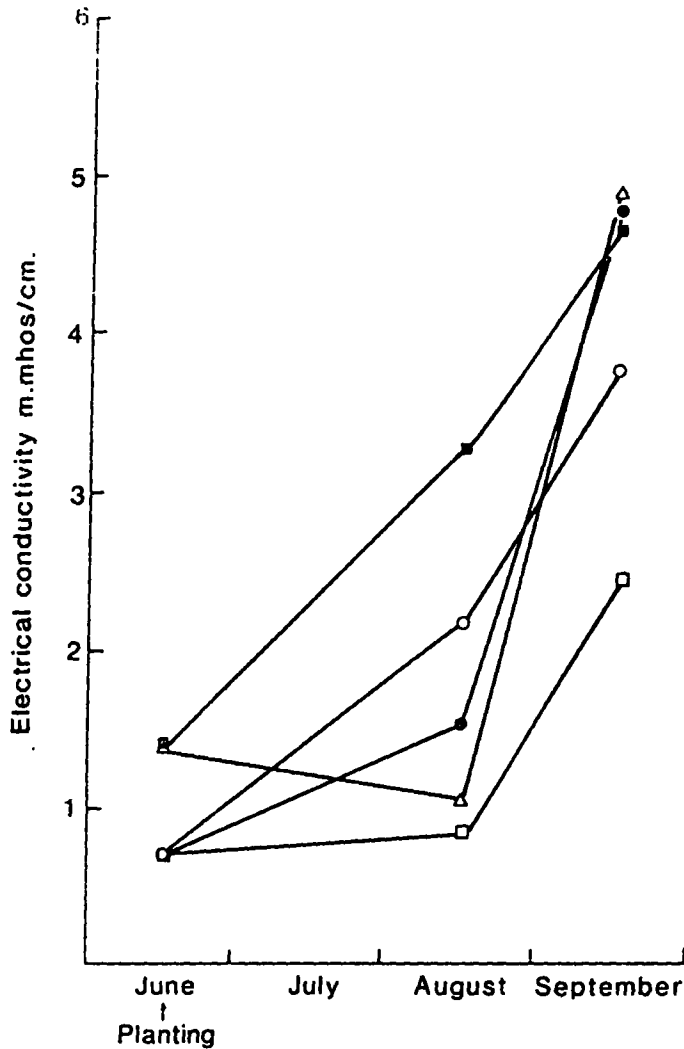
Table 2 Yield: total amount of water applied, average irrigation interval, irrigation season and water use efficiencies of the test crop

	<i>Onion Depletion</i>			<i>Chillies (yala) Depletion</i>			<i>Chillies (maha) Depletion</i>			<i>Banana Depletion</i>		
	10%	40%	75%	10%	40%	75%	10%	40%	Rain	10%	40%	Rain
Yield t/ha	11.5	3.5	3.4	1.59	1.03	0.97	3.02	2.59	1.70	12.87	7.29	5.82
Total water applied-cm	10.7	15.9	17.1	27.5	32.4	37.3	13.5	23.6	3.7	105.5	174.0	73.9
Average irrigation interval-days	1	2	4	1	2	3	—	—	—	1	3	—
Irrigation season-days	70	70	70	107	107	107	121	121	121	269	327	350
Rainfall during the growth period-cm	—	—	—	4.6	4.6	4.6	37.2	37.2	37.2	68.3	68.3	68.3
Total ET of the crop (water use)-cm	13.4	13.3	12.0	27.0	27.3	20.7	42.3	42.2	42.1	98.6	105.6	109.5
Water use efficiencies 1/kg. m ⁻¹	10.6	2.0	1.9	0.5	0.3	0.2	0.5	0.4	0.4	7.1	2.9	3.9
2/kg ha-mm ⁻¹	85.8	24.0	28.3	5.8	3.7	4.6	7.1	6.1	4.0	12.0	6.9	5.3

1/ water use efficiency was estimated dividing the yield per hectare by total water applied per hectare during the growth period for chillies and onion; for banana w.u.e. was estimated, dividing yield per plant by the total water applied per plant during the growth period.

2/ water use efficiency was estimated, dividing the crop yield per hectare by the crop water use (in mm) during their growth periods.

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- Drip irrigation at 10% depletion on Y.L.
- Surface irrigation at 40% depletion on Y.L.
- Rainfed on Y.L.
- Surface irrigation at 40% depletion on R.L.
- △ Rainfed on R.L.

Figure 2. Influence of irrigation treatment on change in soil electrical conductivity at the root zone of onion, (0-30cm. depth)

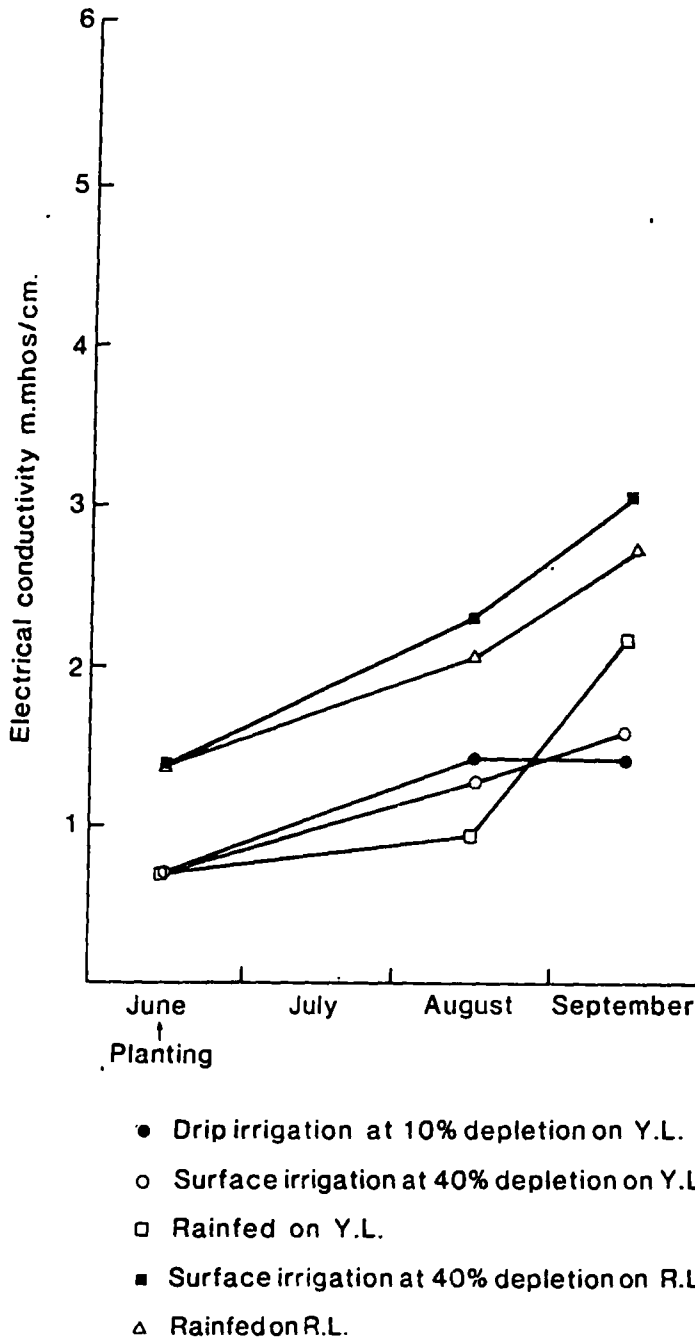


Figure 3. Influence of irrigation treatment on change in soil electrical conductivity at the root zone of chillies, (0-30cm. depth)

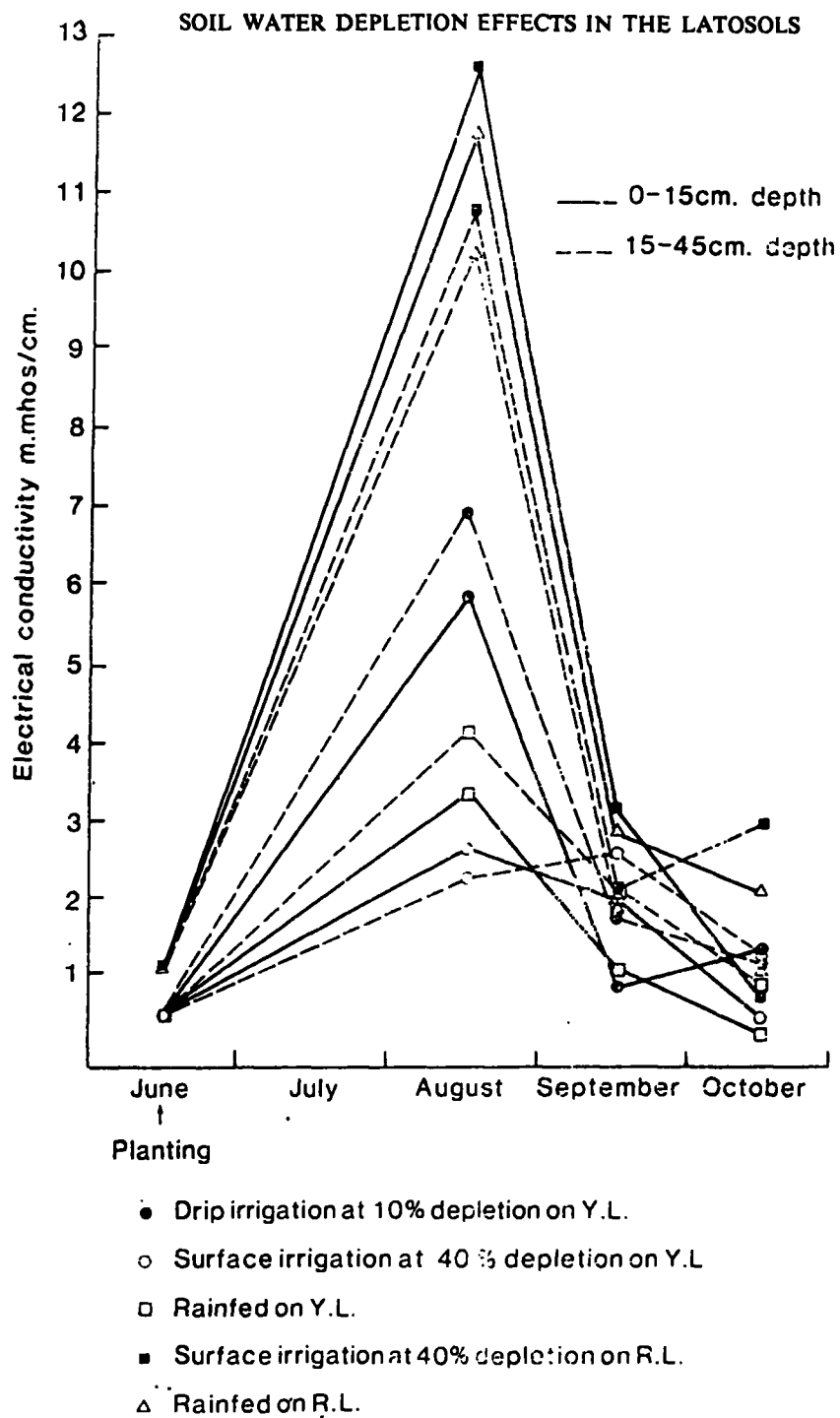


Figure 4. Influence of irrigation treatment on change in soil electrical conductivity at the root zone of banana, (0-15cm. and 15-45cm. depths)

DISCUSSION

The results presented in this paper show that under the experimental conditions, the yield of crops irrigated by drip irrigation under a regime of 10% soil moisture depletion were significantly greater than crops irrigated by surface watering methods at 40% and 75% soil moisture depletion levels. This yield enhancement under drip irrigation has been extensively reported elsewhere e.g. Goldberg *et al.* (1970); Jobling, (1979). The improved yield is generally attributed to the reduction of drought stress (including that due to salinity build-up) between irrigations. The more frequent drip irrigation prevents the soil drying and the accompanying concentration of soluble salts which occurs with less frequent irrigation. The yield improvement is enhanced therefore on sandy soils of low water holding capacities and frequent irrigation by drip allows irrigation water of a higher salinity to be used effectively.

The results also showed that the higher yields under drip irrigation were associated with higher water use efficiency both in terms of water applied and water evapotranspired by the plants when compared with the 40% and 75% soil moisture depletion levels. This is particularly important where water availability is limited and the cost of provision of water is high, as it is under tubewells drawing from the aquifers of the North West Dry Zone. In addition, results from elsewhere (Goldberg *et al.*, 1970) have shown that it is possible to use poorer quality of water with drip irrigation systems than with other methods of irrigation because the high soil moisture content of the soil does not allow the salts to become concentrated in the soil. The results presented in this paper show that the water quality from the Vanathavillu aquifer is poor and there is a potential problem of salinity if proper management procedures are not exercised. The use of drip irrigation certainly offers potential.

An important consideration in the use of drip irrigation though is the economic aspect. The drip irrigation system used in this research was expensive and would clearly be beyond the means of smallholder farmers. The need for research on a plant water delivery system, gravity based and made out of local materials is evident.

A final aspect which was not discussed in the paper but which clearly merits the attention of soil scientists was the fact that all crop yields on the red latosols were significantly greater by an average 20% than those on the yellow latosols. This may be related to fertility characteristics of the soil but it is not known.

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