TRIALS WITH TRICKLE IRRIGATION EQUIPMENT AT MOROGORO PRELIMINARY REPORT

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Abstract

The use of trickle irrigation is discussed with reference to Tanzania. A split-split plot design experiment is described in which yields of tomato, onion, and cabbage are compared for trickle and hand-irrigated plots, with different levels of fertiliser treatment. Yields for trickle-irrigated plots were significantly greater only for tomatoes. These results were achieved during July to October and a second attempt to grow the same vegetables during December to March was unsuccessful. Further trials are required to obtain a suitable rotation of vegetable crops from both a nutritional and agronomic point of view. Experience with the trickle irrigation equipment is also described.

1. Introduction

1.1 General

The majority of the people in Tanzania live in rural areas where the diet is sometimes unsatisfastory. The staple foods are commonly rich in calories but poor in protein and vitamins. These can sometimes be adequately supplemented by those parts of plants which are rich in proteins and vitamins, as calculated per 100 calories of edible portion. The particular type and amount of vegetable required as supplementary food will be based on values given in food tables (Platt 1962) and will be dependent on the compositon of the staple food.

In the semi-arid areas, shortage of water and problems of transportation require small communities to use intensive cultivation techniques to produce vegetables. In order to provide assistance to such communities the Water Development and Power Ministry has undertaken the modification of a recently developed system of irrigation, in order to allow local manufacture. This system of irrigation is known as trickle irrigation and is extensively used in other countries, with semi-arid areas, for both fruit and vegetable growing (5,000 and 6,000 hectares in Australia and Israel respectively).

1.2 The System of Trickle Irrigation

Buried plastic pipes are used to deliver water directly to the root zone of individual crops through patented drippers. Each dripper can provide water at rates between a fraction and several litres per hour depending on the particular design and construction. First developed for greenhouses, it was essentially labour saving with conflicting opinions concerning its superiority over other irrigation systems with respect to yield and minimum water use (Boyce 1960) (Van den Ende 1959). More recently field experiments have confirmed improved yields with trickle irrigation over other techniques. In the Arava desert of Israel trickle-irrigated plots of musk-melon, cucumber and tomato outyielded comparable plots irrigated by sprinkling and by furrow (Goldberg & Shmueli 1970). A similar favourable comparison of trickle with surface irrigation for onions and okra was observed in India (Abrol & Dixit 1972). Finally, in preliminary experiments at Morogoro it was found that with egg-plant, yields from trickle-irrigated plots were significantly higher than those from surface-irrigated plots.

Further experiments were conducted at Morogoro to investigate the following topics:

a) to see if improved yields could be achieved for other crops when equal amounts of water were applied by trickle irrigation and by watering can. The quantities of water applied were to be based on the assumed needs of the trickle-irrigated plots.

b) to attempt to provide simple associated fertiliser recommendations.

c) to see if two crops could be obtained per year.

d) to evaluate the perfomance of the various components of the trickle irrigation system.

e) to attempt a preliminary assessment of costs.

2. Experimental Procedure

2.1 Site Preparation

A plot (0.1 hectare), adjacent to the department of Agricultural Engineering, was mechanically levelled to ensure even water distribution in hand irrigated plots.

Fig. 1

Experimental Layout for Split-Split Plot Design

Irrigation Treatments	Fertiliser levels	Crop	Blocks
	2 3 1	O	
H	1 2 3	C	
	2 3 1	T	1
	1 3 2	O	
S	1 2 3	T	
	3 1 2	C	
	3 2 1	C	
S	2 3 1	T	
	3 1 2	O	2
	2 1 3	C	
H	1 3 2	O	
	2 1 3	T	
	3 2 1	C	
S	3 1 2	O	
	1 3 2	T	
	1 3 2	O	3
H	3 2 1	T	
	1 3 2	C	
	3 1 2	C	
S	1 2 3	O	
	2 1 3	T	4
	3 2 1	T	
H	1 2 3	C	
	3 1 2	O	
	3 2 1	C	
H	3 1 2	T	
	1 3 2	O	5
	1 3 2	O	
S	2 1 3	T	
	1 2 3	C	
	3 2 1	C	
S	2 3 1	O	
	3 1 2	T	6
	2 1 3	C	
H	3 2 1	T	
	1 3 2	O	

	2	1	3	C	
H	2	3	1	T	
	1	2	3	O	7
	3	2	1	T	
S	3	2	1	C	
	2	1	3	O	
	2	3	1	C	
H	2	3	1	T	
	1	3	2	O	8
	1	3	2	T	
S	1	3	2	C	
	2	1	3	O	

Key : H — hand irrigated
S — trickle irrigated
C — Cabbage
O — Onion
T — Tomato
1, 2 and 3 — fertilizer levels

Top soil was initially removed then later used to make beds. The area had not been cultivated for several years and was a red clay loam of the oxisol order. This soil was fairly well drained though not particularly suited to vegetable production. This choice was deliberate in view of the need to produce realistic yields which could be achieved by the local farmers (F.A.O. 1973). Forty-eight beds, 1m. by 15m., were made up by hand with 0.6m. width paths between each, after the area had been cultivated with a spring-tined cultivator. Wide paths were used to avoid experimental complications but would normally only be 0.3m. wide. A composite sample of soil, taken from a depth of 0 to 15cm. before trial work, was analysed as follows :

Soil pH	Conductivity	Organic Carbon	Soil Potassium
7.4	0.350 million hos	1.38%	28 p.p.m.

2. 2 Design of Experiment

Given the constraints of the design and layout of the trickle irrigation system a split-split plot design was used with irrigation systems as the main treatment, then crops forming the first split and fertiliser levels the second. Eight replications were used since the design afforded least sensitivity to the comparison of irrigation systems, see fig. 1.

The three vegetables chosen were tomatoes (Money maker), cabbage (Glory of Enkhuizen), and onions (Red Globe). These were chosen on the basis of similar growing season and so that the different edible parts of a plant were included; notably the fruit, vegetative part and bulb. Plant spacings were decided on the basis of tables from handbooks and after discussion with staff at the Faculty Horticulture Unit. The chosen spacings were for tomatoes, 1m. apart in rows 0.6m apart, for cabbage, 0.5m. apart in rows 06m. apart and for onions, 0.15m. apart in rows 0.6m. apart During the second season the tomato spacing was reduced to 0.6m. between plants, otherwise the experiment was repeated as before. Fertiliser applications were chosen on the basis of the soil test results and advice from the Faculty staff. Three levels of nitrogen at the rate of zero, 112 and 224 kg/hect were used in the form of ammonium sulphate. Basal dressings of potassium and phosphorous at the rate of 112 kg/hect were applied as muriate of potash and triple super phosphate respectively.

2.3 Equipment

Trickle irrigation equipment, comprising a 455 1. storage tank, a 51 mm. plastic main lateral pipe and twenty-four 38 mm. diameter longitudinal pipes, was installed by staff of the W.D. and P. Ministry under Mr. Mwalwega. In each block of six beds the first three beds were randomly assigned to either trickle or hand irrigation and the longitudinal pipes fitted accordingly. The longitudinal pipes were buried 10 cm. below the soil surface along the middle of each bed. Microtubes of 0.75 mm. inside diameter were attached to the longitudinal pipes at 0.5 m. intervals. Each microtube was 28 cm. long and provided an individual delivery of 1.14 1/hr. This length was chosen from hydraulic design tables (Felföldi 1969) to provide the given discharges when the elevated storage tank delivered water to each tube at a pressure equivalent to a head of 0.914 m. water. Frictional losses were found to be neglible so that each microtube was assumed to have the same delivery rate. Each microtube had agravel filter head to prevent silt blocking the microtube. Although piezometers were fitted to ensure accurate control of discharge rates, a water meter was also fitted between the main lateral and water tank, in order to check these rates. Hand watering was accomplished by hose pipe, fitted with water meter and watering-can head. Tensiometers were also installed at 15 and 25 cm. depth, midway between tomato plants in singie rows, in both hand and trickle-irrigated plots.

Although longitudinal pipes were flushed out weekly the gravel head filters often became blocked. During the second growing season counts were made of the required frequency of clearing blocked heads. Water applied

by trickle irrigation was also metered and the required time for irrigation checked with the expected time, based on the predicted gravel filter-head discharges of 1.14 l./hr.

2.4 Crop Management

Seedlings of the three crops were raised in a nursery with the tomatoes and cabbage also transplanted into polythene bags containing rich soil, prior to planting in the experimental area during May and November. It was expected that residual fertiliser would be leached from the plots during the onset of the short rains and before transplanting the second crop. The triple super phosphate was applied 25 mm. below the seedling during transplanting whilst ammonium sulphate and muriate of potash were applied 25mm. deep and 75mm. from the plant, three weeks later.

Tomatoes and onions were sprayed with a fungicide 'Blitox' whilst cabbages were sprayed with an insecticide 'Malathion'. Spraying was done initially twice per week. Only one weeding was required during the first growing season but several times during the second. Tomato-staking and desuckering was done three weeks after transplanting.

2.5 Watering

To estimate crop water requirements, water was assumed to be lost from a 0.6 m. wide strip along the bed. Values of potential evapotranspiration derived, using the Penman equation, for Morogoro (Woodhead 1968) were used to calculate water requirements. Crop factors of 0.8, 1.2 and 0.8 were used for the main three months of the growing season. Totals were increased by 20% to allow some leaching and watering, both by hand and by trickle equipment, was done three times per week. Attempts to water each day only produced a wetted zone of 100-150 mm. diameter which was likely to produce salt concentrations within plant root zones rather than at the edges. Almost rain fell during the first growing season with a small amount during the second. Modifications were made to the watering regime, whenever necessary, in order to maintain the soil moisture tension in the range 15-25 cm. Hg. Specifications for the tensiometer indicated that readings of 3-6 cm. would correspond to conditions of "field capacity" whilst the 30 cm. position corresponded to loss of half the available moisture at that depth. Measurements were made to determine the moisture sorption curve and moisture samples were taken, using a soil auger, for gravimetric analysis and comparison with tensiometer readings.

3. Results

3.1 Crop Observation and Yields

During the early part of the growing season a striking colour difference was observed between the cabbages on each system. Cabbages irrigated by hand developed a deep green to blue colouring whilst those on trickle-irrigated plots had a light green appearance. The colour difference was evident between plots having no nitrogen fertiliser. Recent experiments with sub-irrigation, by water table control, on Bentgrass report the same phenomenon (Krans & Johnson 1947). The reduced colour associated with sub-irrigated treatments was correlated with significantly lower chlorophyll production by comparison to sprinkler irrigated plots. Adequate soil nitrogen levels during the period of chlorosis showed that metabolism and/or assimilaition of nitrogen may have been adversely affected by lack of oxygen or presence of toxic compounds such as nitrite nitrogen found under anaerobic conditions.

Dissolved fertilisers were also brought to the surface and tended to remain so for the trickle-irrigated plots. Whilst the tomato crop remained quite healthy there were some signs of virus infection and blossom end rot.

TABLE I

Mean total crop yields in 10^3 kg/hect (June-October) (based on path width of 0.3m)

Fertiliser Levels	Trickle Irrigation			Hand Irrigation		
	Tomato	Onion	Cabbage	Tomato	Onion	Cabbage
1	**37.27**	4.38	22.18	28.19	5.38	20.57
2	53.26	9.60	36.60	42.69	6.16	27.07
3	49.32	9.41	24.83	40.43	5.86	33.98

Statistical analysis of all data contributing to the total shown in Table I indicates that trickle-irrigated plots significantly outyielded surface-irrigated plots by 4.06 x 10^3 kg./hect at the 5% level of significance, considering all crops. Only the yield of tomatoes from trickle-irrigated plots singificantly ouyielded hand-irrigated plots. Fertiliser levels had a very highly significant effect on yield of vegetables. For the trickle-irrigated plots the second fertiliser level significantly outyielded both the first and third levels by 11.8 and 5.31 x 10^3 kg/hect respectively. In this respect tomatoes, at the second fertiliser level, significantly outyielded the first level by 15.99 x 10^3 kg/hect and outyielded the third level by 3.94 x 10^3 kg/hect which was significant.

Similar results have recently been reported for cabbage (Bucks et al 1974). Cabbage production with trickle irrigation was the same as for furrow-irrigated plots when water use was applied at 1.3 and 1.05 times the consumptive-use requirement for furrow irrigation. Yields were decreased 10 and 43% respectively, compared with the higher watering rates, when 0.8 and 0.5 times the consumptive use requirement were applied. Yields of furrow irrigated crops at low watering rates were reduced to a greater extent. Frequency of trickle irrigation caused no difference in production between 3, 6 and 12 day applications at the 1.3 consumptive use quantity. Yield reductions did result for the 3-day frequency at 1.05, 0.8 and 0.5 consumptive-use quantities, amounting to a 90% mean reduction for the 3-day compared to the 6-day frequency, and a 13% mean reduction for the 3-day compared to the 12-day frequency for the three smaller quantities.

Considerable difficulty was experienced during the transplanting of crops in early December, especially the onions. Although it was not possible to sterilize the beds the experiment was exactly replicated in order to avoid interactions of one particular crop following another. Consequently the tomato crop was affected by nematodes. The cabbage and onions also failed to develop, notably both within the experimental area and some distance away at the Faculty's Horticulture Unit. Whilst it would normally be uneconomic to harvest such poor crops this was done and showed yields to be only one tenth of the previous season. Red and yellow discolouri-sation was observed on the edge of cabbage leaves during harvest. The low altitude (530m a.s.l.) at which this work was conducted, leading to heat stress in the crops, may offer some explanation of the crop failure.

3.2 Observations on equipment

When applying 82 l./bed, the required time to complete irrigation was 40 per cent longer than the expected time based on the microtube rating. Considerable sediment was being brought into the system despite the large gravel filter used in the storage tank. On average, nine gravel heads became blocked during each irrigation, that is one in every eighty heads.

3.3 Watering rates

During July, August and September watering rates were 37, 55 and 55 l./bed/day. These amounts were sufficient to maintain the soil moisture tensions in the range 15-25 cm. Hg. for trickle-irrigated plots though tensions rose to 60 cm. and above in hand irrigated plots. Comparison with the estimated requirements shows that crop factors of 0.8, 1.0 and 0.9 would have been most suitable for purposes of prediction of water requirements.

During December 55 l./bed/day was used but with intermittent showers occuring throughout the rest of the season 41 l./bed/day was generally adequate to maintain the desired soil moisture tensions. This was only half the expected requirement, though signs of wilting suggested that wilting was occuring despite adequate soil moisture conditions in the root zone.

It was not possible to establish any clear interpretation of gravimetric soil moisture measurements with regard to either the two irrigation systems or the variation of soil moisture depth. However, tensionmeter readings clearly indicated less moisture in hand-irrigated beds and decreasing moisture with depths up to 25 cm.

4. Conclusions

Whilst overwatering could have hidden differences in the efficiency of water used for the two irrigation systems this was thought not to be the case and significantly improved crop yields were only observed for the tomato crop. Further tests to include watering rates below the optimum should perhaps be made to confirm this, though work by Bucks does establish that the optimum quantity, on which to base water applications for maximum production with trickle irrigation, is comparable to consumptive use estimates for the standard furrow method.

Applications of nitrogen, potassium and phosphate fertilisers at the rate of 112 kg/hect were found necessary to achieve good yields of tomatoes and cabbage. Difficulties were experienced in obtaining two harvests during the year and it was felt that better varieties would be necessary before full use of trickle irrigation facilities could be achieved. When tomatoes and similar crops, such as egg-plant and red peppers, are grown then a rotation would also be necessary to control nematodes.

Since these findings conflict with other findings elsewhere with regard to improved yields there would be a need for further work with particular attention to the importance of soil nutrient status. To achieve the aim of improving nutrition levels in rural areas it would appear equally important to find the right combination of vegetables suitable to complement typical staple diets and which could also form a practical rotation.

Estimates of water requirements based on values of Penman potential evapotranspiration (Woodhead 1968) with 20% excess for leaching and crop factors in the range 0.8-1.0 appear adequate. However, further tests should be made on existing installations to investigate any reduction of microtube discharge rates with time or water sediment load. Modifications to the design should be considered to examine whether or not an improved filter (N.Z.A.E.I. 1971) can be included to prevent blocking of microtubes.

The initial investment involved in providing the trickle irrigation facilities was T. Sh. 6,236.20. Material costs contributed almost 60% of the total cost, with salaries, hire and renewals making up the rest. If the optimum production of tomatoes, achieved above, could be maintained over the five year life of this investment, then with a 5% interest rate and with only one harvest per year, the cost per kilo over and above other costs would be Sh. 0.60. The need for good management to achieve reasonable returns on the investment is correspondingly emphasised.

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