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Yield of tomato grown under continuous-flow drip irrigation in Bauchi state of Nigeria

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ABSTRACT

Current global concerns on attainment of food security and poverty alleviation require new strategies with marked potential for water conservation and yield increase. This informed the design of an affordable continuous-flow drip irrigation system that applies the exact peak crop water requirement continuously throughout the 24 h of a day, and so maintains the crop root zone near field capacity all through the growth season. The design continuous-flow rate was nine drops of water per minute (0.03 l/h) for tomato used as test crop. The system was constructed from inexpensive off-the-shelf components, incorporating the medical infusion set as emitter. The drip system was evaluated in Bauchi State, Nigeria during the 2003/2004 and 2004/2005 irrigation seasons under four continuous-flow rates of 0.03, 0.05, 0.06, and 0.07 l/h against a bi-daily application as the control. The recorded yields were 42.9, 42.6, 44.4, and 44.4 t/ha, respectively for the four treatments and 22.3 t/ha from the control. The associated Water Use Efficiencies were 15.5×10^{-2}, 10.7×10^{-2}, 8.5×10^{-2}, and 6.4×10^{-2} t/ha mm in same order for the four discharges, while that of the control was 10.1×10^{-2} t/ha mm. The continuous-flow drip schedule offered water savings of about 42.3 and 15.7% at 0.03 and 0.05 l/h, respectively over short level impoundment furrow irrigation widely used by resource-poor farmers in Nigeria. However, at the higher discharges of 0.06 and 0.07 l/h, the system rather applied 10.1 and 32.2% additional water over furrow irrigation. Results of this study summarily demonstrate promising prospects of the affordable continuous-flow drip irrigation system in delivering high crop yields especially if the crops are grown under appropriate agronomic practices that enable protraction of the growth season. The recommended range of continuous dripping for tomato is 0.03–0.05 l/h.

1. Introduction

Most comprehensive blue prints to attain food security in developing countries underscore rapid development of the irrigation sub-sector. However, as we strive to obtain higher yields from finite and heavily used natural resources, the rate of soil loss accelerates, and fresh water supplies become the more impoverished due to misuse and overuse. The concept of affordable micro irrigation technology (AMIT) currently being promoted by organisations like Chapin Watermatics Inc. and International Development Enterprises (IDE) is apparently a very potent strategy to augment agricultural production from the traditionally irrigated small-holder plots within rural communities of developing countries in a cost effective and

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water efficient manner. Unfortunately, the operational principles of these low-cost micro irrigation systems require that water be applied 2–4 time daily or sometimes even more (Polak et al., 1997; ALIN, 2002; IDE, 2003; Masimba, 2003; Anon., 2004; UNEP, 2004). This practice requires recurrent farm visits that manifests in increased systems running cost. An affordable continuous-flow drip irrigation system was therefore designed in which the peak crop water requirement is supplied continuously throughout the 24 h of a day. This would reduce the number of farm visits and so accord rural farmers ample time to undertake other off-farm revenue generating activities. The continuous-flow drip irrigation principle is therefore aimed at boosting the production and income level of resource-poor farmers and so help towards poverty alleviation in rural communities of developing countries. The system was constructed and tested in Bauchi state Nigeria with tomato as experimental crop. The results are presented herein.

2. Materials and methods

2.1. The experimental site

Bauchi state is one of the 36 states of the Federal Republic of Nigeria. The research was conducted specifically along the *fadama* irrigation research plot of Abubakar Tafawa Balewa University, Bauchi. The University is situated in Bauchi local government which falls within the Northern Guinea savannah ecological zone of Nigeria. This region lies within latitude 10°17′N and longitude 09°49′E on a mean altitude of 609.3 m above sea level. The dry season in this region starts from late October and extends to April, sometimes May. These months are characterised by the cool dry harmathan wind especially from November to February. Ambient temperatures during this period is between 10 and 37 °C, which favors growth of cold weather crops like tomato, potato, and carrots amongst others. The soil of the experimental plot was predominantly sandy loam from the surface to 300 mm depth and then clay loam from 300 mm depth down to 600 mm taken as the effective root zone depth of tomato (Mudiare and Kwayas, 1995).

2.2. Systems design

The system was designed for tomato as test crop. Tomato was chosen as experimental crop because it is a row crop and thus adaptable to drip irrigation. The peak daily crop water requirement was calculated as the product of reference crop evapotranspiration and the peak crop coefficient of tomato. Reference crop evapotranspiration was calculated using the FAO version of the Penman–Montieth equation according to Allen et al. (1998) for the duration of the irrigation season. The highest value obtained (5.5 mm/day) was taken as peak ETo. Peak crop coefficient was taken as 1.1 for tomato grown in the Nigerian guinea savanna (Mofoke et al., 2003). The peak crop water requirement for tomato was eventually calculated as 6.1 mm/day. The area to be irrigated by an emitter was computed from Eq. (1) (James, 1988):

$$A_i = \frac{LSP}{100N_e} \quad (1)$$

where A_i is the area irrigated by an emitter, m^2/emitter; L the spacing between adjacent plant rows, m; S the spacing between emission points, m; P the percent of cropped area being irrigated; N_e is the number of emission devices at each emission point.

The variables L, S, and P are subjective design parameters depending on crop, soil type, and economic consideration. L and S were taken as 600 and 450 mm, respectively, following recommendations of Cornish and Brabben (2001). P was pegged at 68%, a value considered safe enough, relative to the minimum 33% suggested by Karmeli et al. (1985). These values gave A_i as 0.1 m^2, which is taken to be the area of influence contributing to the evapotranspiration requirement of each crop stand. Therefore, for an actual crop evapotranspiration of 6.1 mm/day, close to 0.6 l (610 ml) of water is assumed to be consumed by tomato daily through evapotranspiration from an area of about 0.1 m^2 around the crop. This required that 610 ml of water be supplied to the crop daily at a pre-determined steady rate. Attainment of this implied an average discharge of 7.1×10^{-3} ml/s given that 1 day constitutes 86,400 s. This is an exceptionally small delivery rate that could be achieved only by emitters with very efficient-flow regulator. This justifies use of the medi-emitter for this system because it has an effective discharge regulator, and is widely available even in most rural communities. Preliminary hydraulic tests of the medi-emitter revealed that 15 drops of water from the emitter amounts to 1 ml. Therefore, 7.1×10^{-3} ml/s translated to 0.1 drops of water per second or 6.3 drops/min. A 30% safety proportion was added to this amount to obtain a discharge of 8.2 drops/min. However, since 8.2 drops of water is practically difficult to measure, the design discharge was rounded to 9.0 drops/min equivalent to 0.03 l/h. The operational precept of the drip system designed in this study was therefore to apply water to the crop using the medi-emitter, at a constant rate of 0.03 l/h throughout the growth season. Supplying the crop water requirement continuously at this rate under gravity from a reservoir would minimize the number of farm visits and hence labor requirement for irrigation.

2.3. Systems description and construction

The field was partitioned into four plots (3 m × 3 m) to reduce the pressure head requirement at the distributary tanks. Fig. 1 shows the system layout. Each plot was supplied by a separate distributary tank as shown in Fig. 1. Gate valves were placed at the outlet of each distributary tank to control the exit flow, while float valves were fitted at the inlet of same tanks to maintain constant pressure that would ensure steady discharge. The plots were interconnected and eventually linked to two main water reservoirs situated at the farm gate. The mains and manifolds were buried 200 mm below the soil surface to avert their destruction during farm activities. Two types of low-cost filters were improvised for the system: A primary filter, made of 10mm thick foam placed at the pipe intake from the main water reservoir, and a secondary filter adapted from automobile fuel filter inserted along the main pipeline. Conduit pipe used for electrical wiring was utilized for the laterals, mains and sub-mains. This pipe