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Comparison of Water Use Savings and Crop Yields for Clay Pot and Furrow Irrigation Methods in Lake Bogoria, Kenya

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Abstract
As population grows mainly in developing countries resulting in an increase in water scarcity particularly in arid areas, irrigated agriculture is required to produce more food while using less water, and to do so without degrading the environment. The extent of improvement of water management in arid lands involves very high costs and irrigation methods that can help meet this challenge by giving growers greater control over the application of water is desirable. Clay pot is an efficient and cheap irrigation method that does not require water of high quality. Despite the significant efforts at Kapkuikui informal irrigation scheme to increase food production using furrow irrigation method, production has been declining over time due to water scarcity and fields abandoned as a result of salinity raising the need for improvement of the water productivity using an environmentally sound irrigation method. The objective of the present study was to evaluate water use savings under clay pot compared to furrow irrigation methods using field trials of maize and tomato crops and also soil water balance techniques. In addition, analysis of the salinity of irrigation water and soil at the scheme was done. Results indicate that the irrigation water sourced from springs at the scheme is saline with a salinity of 0.85g/l. The clay pot system was found to be more efficient than the furrow irrigation method by saving 97.1% of applied water for the maize crop and 97.8% for the tomato crop respectively. In terms of yield increases, the clay system was more productive per unit of water than the furrow irrigation method. The maize grain yields was 32.2% higher than that under the furrow, while fresh fruit tomato yields was 43.7% higher in the clay pot system than the furrow.
Keywords: maize, tomato, water productivity, semi-arid.

1. Introduction

The increased water scarcity for irrigation particularly in arid and semi-arid lands (ASALs) and the need to expand irrigated cropped area with less or the same quantity of water to grow food crops to feed the increasing population mainly in developing countries, a need for a more efficient and suitable irrigation methods becomes necessary (FAO, 2000). Despite the significant efforts by the community in Kapkuikui informal irrigation scheme, the study area considered in the present study to increase their food production and thus food security, the available quantity of water which is of low quality for irrigation remains constant. A need therefore arises for the improvement of the efficiency of the current furrow irrigation method in use or replacement with a different efficient and environmental sound irrigation system bearing in mind that ASALs are fragile.

The furrow irrigation system whose soil surface is usually heavily wetted at each irrigation cycle remains vulnerable to weed infestations which compete with crops on water and nutrient consumption as well as the very important factor of direct evaporation of water. These factors drastically reduce water use efficiencies. On the other hand, the clay pot irrigation system is one of the most efficient systems of irrigation known and is ideal for many small scale farmers (Bainbridge, 2001; Mahajar *et al*, 2001; Lovell and Murata, 1998). Since water is supplied underground directly to the root zone without wetting the soil surface, water losses as a result of soil evaporation is minimal. Besides this, the system reduces weed prolification. However, this does not mean that the clay pot, which wets only part of the soil volume in the field, reduces water consumption by plants but rather cuts back on the waste of water due to evaporation, deep percolation and competitive consumption of water by weeds. These reductions on water wastage enhance the crop water use efficiency. The clay pot irrigation technology is a conservation irrigation system, which saves between 50% and 70% of water when compared to the conventional watering can irrigation system (Okalebo, *et al,* 1995). The clay pot system is therefore important when water conservation is crucial. The objective of the present study was to evaluate the water use savings under clay pot irrigation method compared to furrow irrigation method using field trials of maize and tomato crops located in a semi-arid region in rift valley region in Kenya.

2. Materials and methods

2.1 Study area

Field experiments were carried out on a sandy-clay loam site with soil moisture content of 12 vol% and 24 vol%

at wilting point and field capacity respectively during the 2005 short rains growing season at Kapkuikui irrigation scheme. The scheme, that is located in Loboi near Lake Bogoria in Baringo County, is characterized as small scale; informal irrigation system, that has been in operation since the 1940's using water from the swamps and springs occurring around the Lake. The irrigation scheme initially covered an estimated area of 65 ha, however over time the area has decrease to the current estimated 30 ha. The decline in area is mainly due to problems associated with salinization of the soils despite continues expansion over the years. The area receives a mean annual rainfall of 649mm and is therefore classified as arid and semi-arid lands (ASAL), which is inhabited by pastoralists, some of whom are nomads. However, with growing population and the resulting increase in food requirements, cultivation especially of irrigated agriculture has become necessary in the area. The area experiences two seasons of rainfall, with the long rains received during the period March to July and short rains received during the period end of September to November. The received rainfall is erratic and coupled with high evaporation rates results in the area experiencing scarcity of water resources. The present rangeland economy in the area is based on livestock supplemented by irrigated cropping of maize crop (Gerrits, 1994). The sources of water are a series of springs and a wetland that occur around the lake. Despite the potential for irrigation in the area, the quantity of water available for irrigation is low besides being saline. The irrigation method used in the scheme is furrow irrigation that encourages accumulation of salts in the root zone as a result of evaporation. The water is abstracted from the sources using canals and directed using unlined canals to the fields.

2.2 Experimental details

2.2.1 Field details

Four plots (Figure 1) each measuring 5× 4m were considered with irrigation method and crop grown as follows: furrow (maize), furrow (tomato), clay pot (maize) and clay pot (tomato). The plots were prepared by cultivating the soil to a fine tilt with a hand hoe then followed by pre-irrigation to raise the soil moisture content to field capacity followed by direct sowing for maize and transplanting for tomato on 26th November 2005 using the recommended spacing of 45 cm × 15 cm and 60 cm × 30 cm respectively. Between the sub-plots, a dyke of 0.5 m wide was constructed to prevent accidental flow or seepage of water across the plots (Figure 1). A parshail flume was installed, on the field canal, to measure using the rating curve the flow rate (Q) of irrigation water supplied to maize and tomato crops under furrow irrigation method. The irrigation schedule used by the local farmers of twice per week was applied to supply irrigation water under the furrow system. The volume of applied water (V) was obtained as the product of Q and the time of irrigation water application (t).

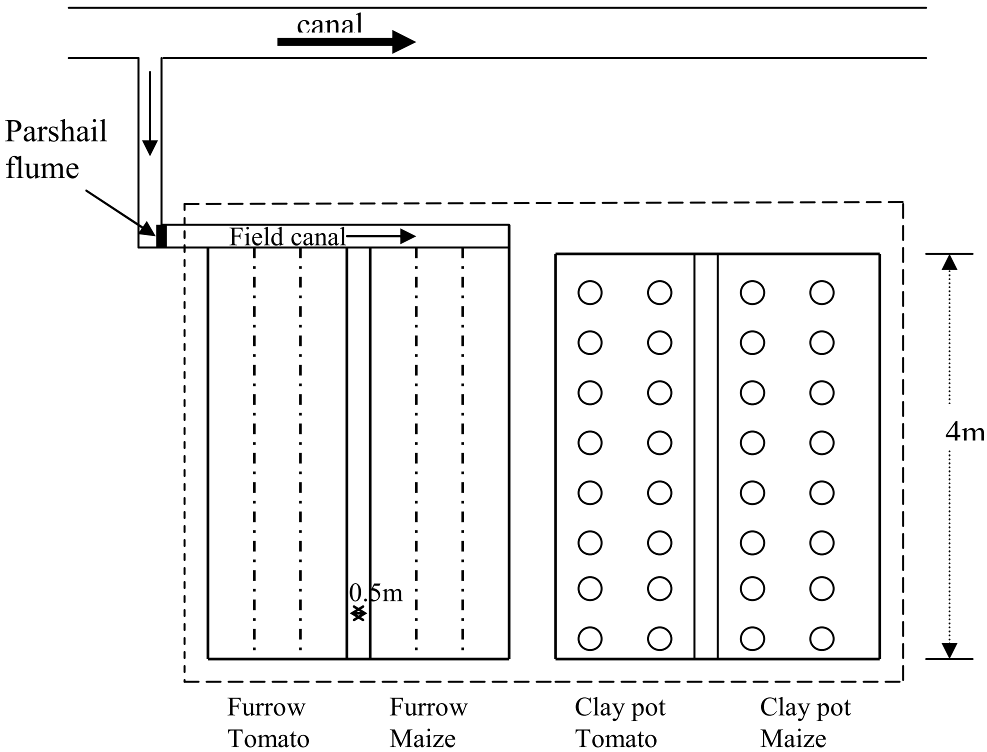

Figure1: Schematic diagram of the field setup for comparing performance of furrow and clay pot irrigation systems.

Adjacent to the furrow irrigation system plots configuration, the clay pot irrigation system was set up in two plots prepared and measured as in the case of furrow irrigation method (Figure 1). Clay pots made locally by rural women measuring five litres in capacity were installed at 0.5 m intervals in a line in the study plots by burying them neck deep in the prepared seed beds. During irrigation the clay pots were filled with water and then covered with ceramic lids to prevent evaporation losses of water and losses from rodents and other small animals drinking from the pots or falling into the pots. Covering of the pots also prevents mosquitoes from breeding in them. Sixteen (16) clay pots were used for each configuration in each plot for maize and tomato respectively. To determine when to irrigate for the clay pot irrigation, 50% pot depletion was considered. The amount of water applied during each refilling event was determined manually refilling the pot using a one litre capacity measuring cylinder.

2.2.2 Climatic data

Lake Bogoria meteorological station measuring daily weather data located 2 km east of the field site was considered. Daily rainfall records from the station were collected for the period of the field experiments. During this period 0mm of rainfall was received. Daily pan evaporation (Epan) records for the station were also collected for the same period and reference crop evapotranspiration (ET0) for the station was calculated by multiplying the pan coefficient (Kpan) by Epan (Allen *et al.,* 1998).

2.2.3 Soil water balance

A soil water balance procedure that estimates reasonably well, the water content in the root zone at the end of each day using available information on soil water availability and plant uptake (Kipkorir, 2002) was used in the present study to compute net irrigation water requirements for no water stress conditions for maize and tomato crops. The procedure is based on empirically established results of plant response to available soil water (Allen et al. 1998; Kipkorir, 2002). The inputs required by the procedure are crop data (crop coefficients and rooting depth), soil data (moisture content at wilting point and field capacity) and daily climatic data (rainfall and reference evapotranspiration). The procedure monitors the soil water conditions in the root zone on a daily basis during an irrigation season by estimating actual evapotranspiration on each day and applying a specified irrigation depth when root zone depletion exceeds the specified irrigation depth that is less than the maximum application depth.

2.2.4 Soil salinity

Using a DR 2000 spectrophotometer (HACC Company) and following the soil pH and electro-conductivity procedure as proposed by Rhodes (1982), the soil in the newly irrigated area was found to have a pH of 7.3 while that of degraded land was found to have a pH of 9.7. In addition, the soil sample was found to have a salinity of 3.83g/l (5.87 milliSiemens/cm) in the irrigated land and 9.98g/l (14.99 milliSiemens/cm) in the degraded areas. Using FAO, 1985 salinity classifications and the above results the irrigated land in Kapkuikui scheme can be said to be slightly saline while the already degraded land can be classified as medium saline. Noting that the current land under irrigation receives annual alluvial deposition and flash floods, the salinization of the soil which is attributed mainly to poor quality irrigation water and improper irrigation practices has been slightly reduced. However, this process will continue and if not checked, the entire irrigated land will eventually suffer complete salinity and therefore degradation leading to abandonment of cultivation.

2.2.5 Water salinity

Water salinity is the amount of salt contained in water. Using Hanna HI9143 conductivity metre, the spring sources irrigation water at Kapkuikui scheme was found to have a salinity range of between 0.83g/l and 0.85g/l. This finding represents a slight to moderate risk of salinity according to the FAO, 1985 classification. Along the field canals and feeders as well as the irrigation furrows, the irrigation water had salinities of 1.14g/l and 1.18g/l respectively. This increase in salinity as the water flows from the water source to the farms can be attributed to the dissolution and erosion of some of the accumulated salts along the canals and furrows by the flowing water. This calls for the use of proper irrigation water management practices and techniques.

2.3 Data analysis

The yield and applied water in each of the treatments were used in a comparative study of the water productivity by considering the water savings of clay pot irrigation compared to the furrow irrigation method. Maize yield for each treatment was determined from the total weight of field grain maize harvested from each plot and dried to 12.5% moisture content. For tomato the fresh fruit weight was determined also for each treatment.

3. Results and Discussion

3.1 Irrigation water applied

In the present comparative study, field experiments of irrigated maize and tomato crops was done by considering clay pot and furrow irrigation systems. The furrow irrigation system was considered as control since it is the type of irrigation method used by the local farmers. For the two plots under furrow system the flow rate in each plot was measured using parshail flume and the flow used to determine amount of irrigation water applied to each field by multiplying it by respective application time during each irrigation cycle. Results indicate that 348,194.58 m^3/ha of irrigation water was applied to both maize and tomato crops during the crop growing season. For the clay pot irrigation system, the water added to the pots based on 50% depletion in the pot was also measured and totaled for each crop. Results indicate that amount of water applied was 10,250.00 m^3/ha for maize crop and 7,605.00 m^3/ha for tomato crop. This represents irrigation water saving of 97.1% for the maize crop and 97.8% for the tomato crop when compared to the furrow irrigation system (Table 1).

Table 1: Comparison of the irrigation water savings under the clay pot and furrow systems for maize and tomato crops

Type of crop	Furrow (A) (m^3/ha)	Clay pot (B) (m^3/ha)	water savings (A-B)/A %
Maize	348,194.58	10,250.00	97.1
Tomato	348,194.58	7,605.00	97.8

The net irrigation water needs for the two crops was determined using water balance techniques in which the crop data, soil data and daily climatic data were considered. Results indicate that for both the maize and tomato crops, the net irrigation requirement was estimated as 3,600m^3/ha.

Comparing the net irrigation water requirements for maize and tomato crops with the furrow irrigation system as the reference, since the system is currently used by farmers in Kapkuikui irrigation scheme, 344,594.58m^3/ha of water would have been saved representing 98.97% savings. The net irrigation water requirements as determined using the water balance technique showed a water saving of 64.88% for the maize crop and 52.66% for the tomato crop compared to the same crops under the clay pot system, representing a water saving of 6,650.00m^3/ha and 4,005.00m^3/ha for the maize and tomato crops respectively (Table 2).

Table 2: Comparison of irrigation water application under clay pot system with net irrigation water requirements for maize and tomato

Crop	Clay pot Irrigation (A) (m^3/ha)	Net irrigation water requirement (B) (m^3/ha)	Water Saving (A-B)/A (%)
Maize	10,250.00	3,600.00	64.9
Tomato	7,605.00	3,600.00	52.7

3.2 Yield comparisons

Results indicated that the maize crop under the furrow system yielded grain yield of 3.645 ton/ha while under the clay pot system grain yield was 4.820 ton/ha, representing a percentage yield increase of 32.2%. On the other hand, the tomato crop under the furrow system yielded fresh fruits of 8.700 ton/ha while under the clay pot system produced 12.500 ton/ha of fresh fruit representing a 43.7% increase (Table 3). The results indicate that the clay pot irrigation system leads to more yield per drop of water compared to the furrow irrigation method. This is explained by the crop root development and distribution that is limited within the wetted bulb around the buried clay pot that determines the amount of water applied and uptake by the crop. This was confirmed in the present study, at the end of the field trial, it was found that the tomato plants had formed mats of fibrous roots all around the clay pot. In this way, the crop enjoyed a direct abstraction of water as it oozed out of the pot.

Table 3: Yield data for maize and tomato crops under clay pot and furrow irrigation systems

Crop type	Clay pot (A) ton/ha	Furrow (B) ton/ha	Yield increase (A-B)/B %
Maize	4.820	3.645	32.2
Tomato	12.500	8.700	43.7

4. Conclusions

From the results obtained from analysis of applied irrigation water and resulting crop yields for each irrigation method in the field trials conducted, it can be concluded that the clay pot system is more efficient than the furrow system by water saving of 97.1% for maize crop and 97.8% for the tomato crop respectively. In terms of yield increases, the clay system is also more productive per unit of water applied than the furrow system. The maize crop grain yields under the clay pot system was higher than that under the furrow system by 32.24% while the fresh fruit tomato yields was higher in the clay pot system than the furrow system by 43.68%. In addition, compared to the net irrigation water requirements for maize and tomato crops in similar ecological condition, the clay pot system was found to be less efficient by 64.9% for the maize and 52.7% for the tomato crops respectively. It is concluded that the clay pot irrigation method is a water saving technology, which optimizes yields per unit water under slight to moderate saline water supply when compared to furrow irrigation method.

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