Background

Most drip irrigation systems operate with high head (>10 meter water pressure). However, currently affordable small-scale low-head drip technologies for individual households are being developed, promoted and adopted in Kenya. It consist of a water supply source (20-litre bucket, 40-100-litre jerrican or 200-litre drum/mini-tank), placed at a head of 0.5-1.0m, from which water flows through a filter and then to row crops planted along the laterals at specified emitter spacing. The pioneer Chapin system includes a bucket or a drum equipped with drip lines and was promoted by KARI and FPEAK in Kenya. The systems have been adapted for use with the conventional piped water supply system. The bucket drip irrigation has proved popular among the small-scale farmers because of its low cost, increased beneficial use of available water, easy management, and high value crops grown. By 2000, KARI had sold over 3,000 bucket kits and 400 eighth-acre kits, most of them through women groups since its introduction in the country in1996.

However, despite the adoption rate, the farmers identified some challenges that needed to be addressed to improve its performance and sustainability (Winrock, 2000; Kabutha *et al*., 2000). This prompted the University of Nairobi in collaboration with the International Water Management Institute (IWMI) and the Kenya Agricultural Research Institute (KARI) to undertake a technical evaluation of, not only the Chapin bucket kit, but other drip systems that can be adopted for low-head drip irrigation.

Design and Development of Locally Assembled Drip Irrigation Systems

Bucket Kit

A simple locally assembled low-head drip system called *dream drip kit*, was designed and developed to address most of the limitations identified by farmers. It consist of a water supply source, 20-litre bucket, placed at a head of 0.8m, from which water flows to drip laterals through a filter to the crops planted along the laterals. The bucket kit has been up-scaled to 40-100-litre jerrican or 200-1,500-litre drum/mini-tank kits. The dream drip kits are simple, low cost, flexible, easy to install, operate and maintain, and are up-scalable in terms of emitter spacing, water requirement and irrigable area.. All the components of dream drip kits are locally available.

The system was adapted from Chapin kit in which the complicated filter-cork connection was replaced by a simple elbow connection, which is fitted with a filter that can be plugged in and out easily from inside the bucket (see Fig. 1). The filter connection was further modified to allow quick dismantling to ease bulk transportation—piling a number of buckets together. This was achieved by using a threaded galvanized iron socket from which the nippled filter is screwed from inside the bucket and the outlet nipple screwed from outside.

The bucket and the drip laterals are connected through a 0.8m long, clear and flexible hose-pipe, which is connected to a PVC header connector. The header connector is fitted with PVC pipes up to the required lateral spacing. The PVC pipes are then fitted either to a tee connector for a kit with more than two laterals or to elbow connector, from which the drip line (barb) connectors are force-fitted. The clear hose pipe is used to allow detection of airlock that may affect water distribution due to reduced pressure head. If airlock is detected, the elbow connection to the bucket is slightly pulled out and pushed in to release trapped air. This priming process is done repeatedly until the clear hose pipe is filled with water—all the trapped air is released to enable attainment of the required head.

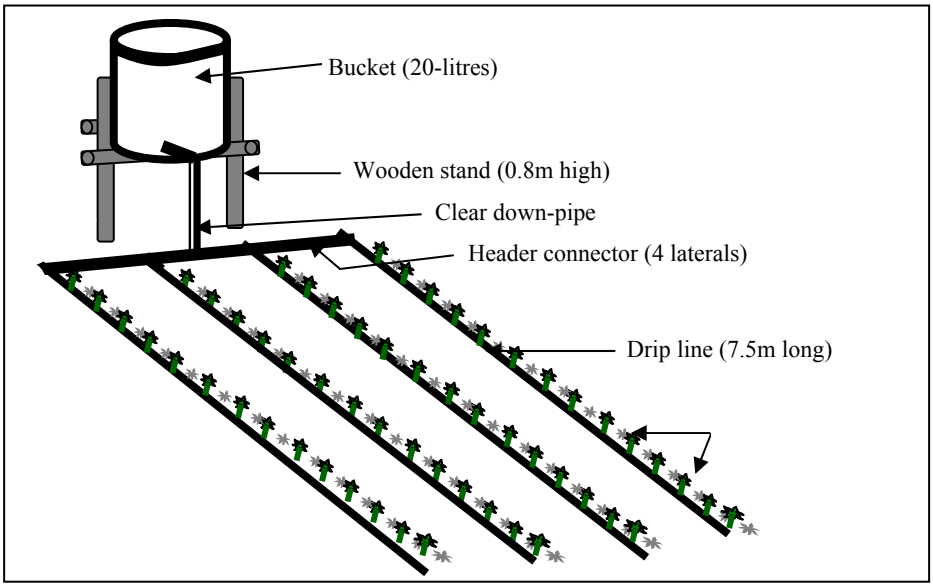

Fig. 1. Typical dream drip kit 20-litre bucket irrigation system

Jerrican and Drum or Mini-Tank Systems

Depending on the farmers' preference, intermediary systems with storage capacity between 20-1,500-litre are also available. The bucket kit can be up-scaled to 40-100-litre jerrican system raised at 0.8m. The drum/mini-tank systems range from 200-1,500-litre raised at 1.0 - 1.5m depending on the method of water delivery. The mini-tank system can even be up-scaled up to 5,000-litre where bigger storage facilities are available or where the system can be connected directly to a household water supply system. Thus the micro-irrigation system can be used to cover between 15-4,000m^2. The cost of intermediary and up-scaled systems is proportional to the size and material used, though bigger system are cheaper due to economy of scale. The 200-litre drum is held horizontally with the inlet on the upper side while the mini-tank orientation is similar to the bucket or jerrican system (see Fig. 2).

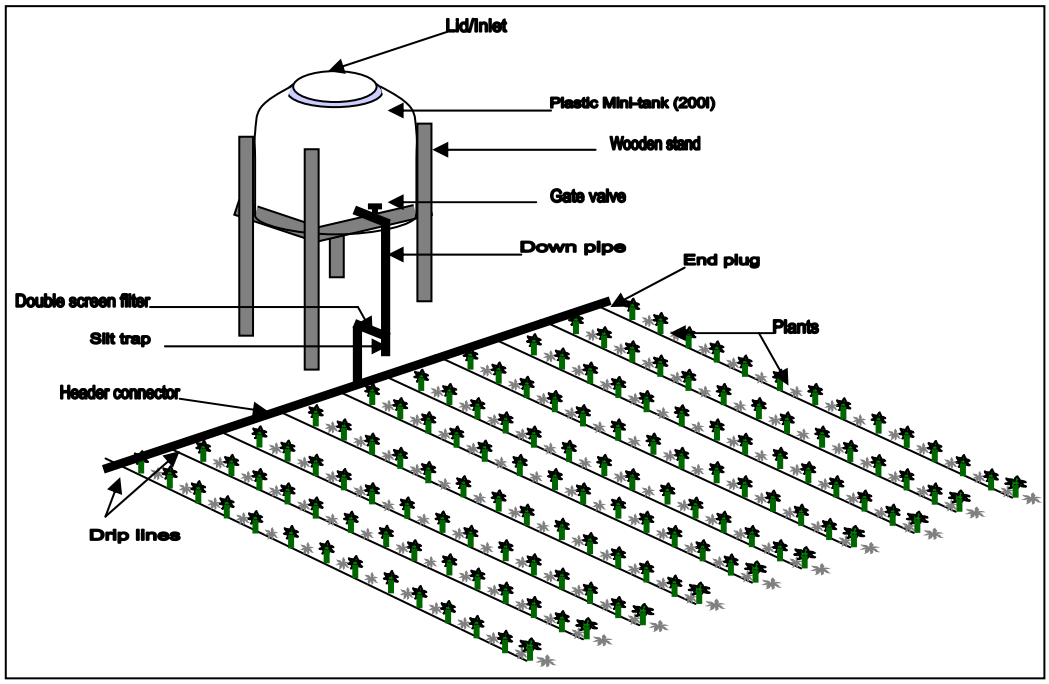

Fig.2. Layout of dream drip kit mini-tank (200-litre) irrigation system

Like the bucket kit, the jerrican, drum or mini-tank drip irrigation kit is assembled from locally available materials. All the accessories are made of 2.5cm diameter low pressure polyethylene (PE) pipes and PVC connectors. The outlet system is fitted with a double screen filter and a silt trap at the lower end. This is done to allow enough pressure to push the water through the dense screen filter. Any debris and solid particles are collected by the silt trap, which is flushed regularly. The barb (lateral) connectors are directly fitted to the PE header connector at predetermined spacing based on crop to be grown. The header connector is fitted with removable end plugs for flushing any silt that may pass through the filter. To ease transportation, the header connector is cut into short pieces (e.g. 1.2 - 1.5m each for 2 laterals), and provided with simple force fit connections.

The optimal height for placing the water supply reservoir is mainly based on ergonomics—level that will allow an average person to refill the drum/mini-tank using a 20-litres container without straining—in case of manual refilling. In most cases, a height of 0.8m is ideal, which means that the inlet will be less than 1.2m. This eases manual refilling of water, which is common in most rural situations. The effect of water supply head (*see section 4.3*) between 0.5 – 1.5m was no significant and hence lower heads will not drastically affect water distribution uniformity. However, if the drip kit is near a water source (a shallow well, stream or reservoir (farm pond, water pan, earthdam or underground tank) it may be refilled by a simple manual pump (hand pump or treadle pump) or motorized pump. A hose pipe from a yard connection water supply may also be used. In such cases, a higher head can be achieved.

To regulate the flow of water, a gate valve is fitted at the outlet (Figs. 7 & 8). The gate valve is closed after the drum/tank is empty and then the drum/tank is refilled for the next irrigation. The header is connected to 10-20 laterals depending on topography, i.e. more lateral for the flat land and fewer for gently sloping land to enhance emission uniformity. The emission uniformity can be further enhanced by ensuring that the header connector is at 0% slope. Otherwise the laterals on the lower side will receive more water leading to low water distribution uniformity.

The dream drip kit bucket irrigation system has also been adapted for irrigating tree nursery seedlings as shown in Fig. 3. This need was first identified during a community training in *Mwanza*, Tanzania.

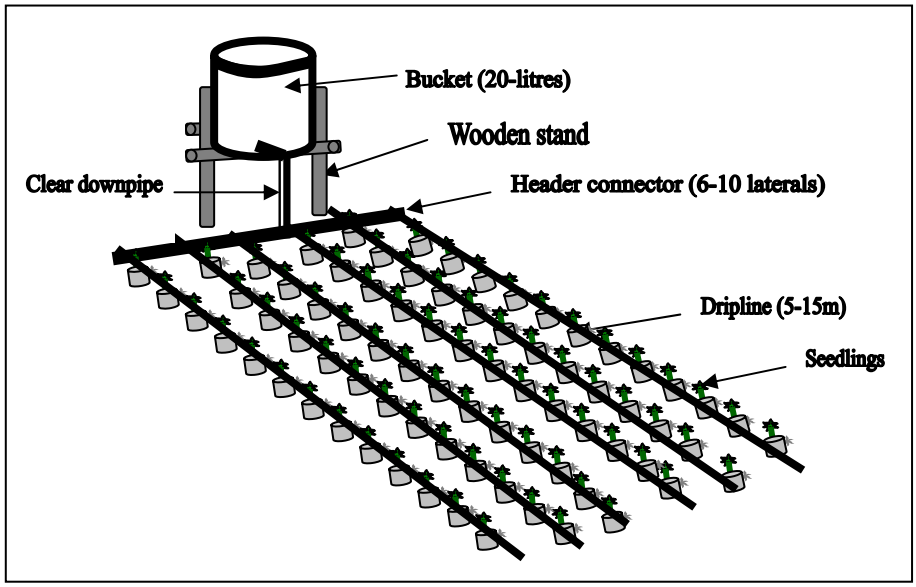

Fig. 3. Dream drip bucket kit adaptation for irrigating tree nursery seedlings

Promotion and Adoption

Most rural communities consist of subsistence smallholder farmers whose low income hinders adoption of a complex technology that would improve their livelihoods. Their knowledge level may also affect adoption of a complicated technology. These factors were considered in the design and development of "dream drip kits". The complicated, delicate and fragile imported low-head drip system was simplified and localized to make it attractive to rural farmers. Its installation and management is within the capacity of most smallholder farmers, even those without prior knowledge of drip irrigation technology. The "dream drip kits" are low-cost and hence affordable. Table 6 shows that the cost ranges from US$ 22 for the smallest unit to US$ 172 for the 200-litre mini-tank (drum) kit and US$ 357 for larger systems (a 500-litre mini-tank kit, which can irrigate up to 1,000m^2). Except for the bucket adaptation for tree nursery, the cost per unit area decreases with the size of the drip kit due to economy of scale. Socio-economic analysis revealed that a benefit: cost ratio of up to 4 : 1 can be attained within a 3-month growing season (Ngigi *et al*., 2005; Ngigi, 2001 & 2002; Winrock, 2000; and Kabutha *et al*., 2000).

Table 6. Specifications and cost of dream drip kit irrigation systems (1US$ @ Ksh. 70)

Specification of dream drip kits irrigation systems	Area (m^2)	Cost (US $)	Cost ($/$m^2$)
20-litres bucket kit: 4 laterals of 7.5m; 2 laterals of 15m or 6 laterals of 5m; and 15 - 30cm emitter spacing	15-20	22	1.14
20-litres bucket kit for tree nurseries: 6 laterals of 10m; 8 laterals of 7.5m or 10 laterals of 6m; and 10 - 15cm emitter spacing	6-10	34	3.38*
40[50]-litres jerrican kit: 4 laterals of 15m; 6 laterals of 10m or 8 laterals of 7.5m; and 30 - 60cm emitter spacing	30-40	40	1.09
60[70]-litres jerrican kit: 6 laterals of 15m; 12 laterals of 7.5m or 8 laterals of 10m; and 30 - 60cm emitter spacing	50-60	62	1.00
80-litres jerrican kit: 8 laterals of 15m; 12 laterals of 10m; 16 laterals of 7.5m; and 30 - 60cm emitter spacing	60-80	75	0.99
100-litres jerrican kit: 10 laterals of 15m; 16 laterals of 10m or 20 laterals of 7.5m; and 30 - 60cm emitter spacing	80-120	93	0.90
150-litres mini-tank Kit: 12-16 laterals of 15m or 20 laterals of 10m; and 30 - 60cm emitter spacing	150-250	130	0.63
200[230]-litres mini-tank/drum kit: 16 - 20 laterals of 15m or 12 - 16 laterals of 20m; and 30 - 60cm emitter spacing	300-500	172	0.41
500-litres mini-tank kit: 32 – 40 laterals of 20-25m laterals; and 30 -60cm emitter spacing	800-1,000	357	0.31

The attractive attributes, which includes ease of operation, simplicity and durability, have contributed to adoption of dream drip kits in Kenya and to some extent in East Africa. The demand for the dream drip kits for micro-irrigation has been increasing for the last 5 years (2000-2005). Since 2002, more than 200 drum kits, 500 jerrican kits and 800 bucket kits have been sold (WAREM, 2006). Though the bucket kit may be considered as economically unviable (Kulecho and Weatherhead (2006), it has been proven adequate for supplying

vegetables for household consumption. However, for income generation, bigger systems are more viable. The feedback from the users has also been encouraging, in terms of practicability and replicability in diverse climatic areas of the country. External support agencies such as Non-Governmental Organizations (NGOs) and Community-Based Organizations (CBOs) have been instrumental in the promotion of the dream drip kits. Publicity and awareness creation has also been achieved through Nairobi International Agricultural Show (2001-2006), Kenya Rainwater Association (KRA) Annual Exposition (2000-2005), workshops and farmers' demonstration training and field days.

The dream drip kit has won a number of awards during annual *Rainwater Exposition* organized by the Kenya Rainwater Association since 2000. At the international scene, the dream drip kit was entered in the International Contest on Innovative Irrigation Ideas & Technologies for Stallholders sponsored by the World Bank, Irrigation Association, International Development Enterprises, IPTRID/FAO and Winrock in 2001and 2002. It was among the top 5 contestants in both years; i.e. 3rd finalist in 2001 & 2002 (Ngigi 2002 & 2001).

Performance of Dream Drip Kits

The developed dream drip kit performs better than similar systems as shown in the comparison between imported Chapin and locally manufactured Victoria 0.5 drip lines that was adopted. Dream drip kit is also simple, flexible, and adaptable and hence can easily be fabricated and repaired by local artisans and farmers. The kit is durable, especially with respect to the fragile drip laterals, which are strong enough to withstand rough handling. The PVC header connector can also be buried under the soil to reduce the effects of direct solar radiation. For larger systems, e.g. 1/8th or ¼ acre kit, ultra-violent resistant polyethylene (PE) header connector has been adopted to enhance durability. Adoption of dream drip kits has made an impact as a means to grow the much-needed vegetables and also for income generation at household level. The reported performance and impact of the dream drip kit is based on feedback from the farmers, some of whom had used the Chapin systems. For example, this has been verified by field evaluation and monitoring in the semi-arid *Ndeiya Karai* area of *Kiambu* district in Kenya, where the drip systems have been in use for 3 years.

The minimum investment cost and high returns of the system shows that minimum amount of water can be used effectively for supplemental irrigation especially for kitchen gardening. A number of external support agents (e.g. Sida supported Regional Land Management Unit (RELMA), Dutch supported Semi Arid Rural Development Program (SARDEP), Danish supported *Kitui* Agricultural Project (KAP), USAID supported KRA/GHARP project, and UNDP-DED Community Water Initiative (CWI) through KRA) in their endeavor to promote viable technologies for poor farmers have adopted dream drip kits. The technology is being disseminated in Eastern and Southern Africa by RELMA, Arid Land Information Network (ALIN), WAREM Consultants and the Greater Horn of Africa Rainwater Partnership (GHARP), among other stakeholders.

Past experiences have shown that the investment cost recovery is guaranteed within one season of 3 months for most vegetables (e.g. kale, spinach, tomatoes, etc). Hence this is as a profitable enterprise, especially for smallholder farmers and more so for those initially hand-watering their kitchen gardens. The kits are applicable to different localities especially the semi arid areas where water is scarce. In the absence of reliable water supply, rainwater harvested through surface tanks, underground tanks, shallow wells, farm ponds, earthdams, or water pans can also be used effectively.

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