Open Access Library Journal
2024, Volume 11, e8881
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Design and Development of a Time Saving and Cost-Effective Irrigation Facility for Peasants and Urban Vegetable Production

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How to cite this paper: Benson, G.A.S., Nofiu, A.O. and Adesina, B.S. (2024) Design and Development of a Time Saving and Cost-Effective Irrigation Facility for Peasants and Urban Vegetable Production. *Open Access Library Journal*, **11**: e8881.
http://doi.org/10.4236/oalib.1108881

Received: March 1, 2023
Accepted: March 20, 2023
Published: March 29, 2024

Abstract

Water is a major component of every living organism, the most inevitable in all plant species as it plays a vital role in their growth and development which in turn translates to a high yield of cultivated crops. Scarcity of water in urban and semi-urban areas of the sub-Saharan Africa as a result of adverse effects of urbanization processes and resultant effects of climate change pertinently require for efficient management and use of the scarce resource (water) in order to meet up with the high demand for food by the alarming population increase. A time-saving and cost-effective irrigation system for peasants and urban vegetable production was designed and constructed. The construction of the irrigation system was simple and cost-effective. It was found to easy to be used and requires little or no maintenance. Its simple construction makes it possible to be utilized in wooden or plastic boxes for the nursery and raising of vegetables crops in areas with limited or unavailable land space such as terraces, balcony and rooftop decking. The sub-irrigation system could supply optimally 21.89 liters of water to a 1 m × 3 m seedbed between the spaces of two days and 5 days in a week or as may be required within the time frame of the season. This sub-irrigation facility eliminates the drudgery associated with other methods of supplementary water application and it is more time-management efficient.

Subject Areas

Agricultural Science

Keywords

Water Use Efficiency, Irrigation System, Urbanization, Climate Change, Design and Construction

1. Introduction

Agricultural development is understood to hold the key to economic development for most sub-Saharan countries including Nigeria [1]. One of the fundamental constraints from the perspective of sustainable agricultural growth and development in Nigeria, is the peasant nature of the production system, with its accompanying low productivity, poor response to technology adoption strategies and poor returns on investment. It is imperative that new technology be adopted to promote accelerated modernization, sustainable growth and development in Agricultural sector [1]. Through agriculture, environmental benefits such as sustainable management and renewal of natural resources, preservation of biodiversity, land conservation as well as contribution to the development and viability of rural areas can be derived [2].

Among the most important constraints to development of sustainable agriculture in West Africa is the overdependence of farming systems on rainfall, which increases the vulnerabilities of production systems to climate change and variability [3]. Recurrent droughts and the unpredictability of rainfalls make farmers very vulnerable to climate-related risks [4]. In addition, increased run-off frequency and soil erosion have rendered many agricultural lands degraded [5]. Although, irrigation does assist in combating droughts and make-up for unpredictable rainfall the potential for irrigation can be enormous since the areas equipped with irrigation hardly exceed 5% of the total agricultural area [6].

Sub-surface irrigation has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone [7]. It involves irrigation to crops by applying water from beneath the soil surface either by constructing trenches or installing underground perforated pipe lines or tile lines. Water is discharged into trenches and allowed to stand during the whole period of irrigation for lateral and upward movement of water by capillarity to the soil between trenches (Indian Agricultural Statistics Research Institute [8]. Sub-surface irrigation is also used in the commercial greenhouse production, usually for potted plants. Water is delivered from below, absorbed by upward movement, and the excess is collected for recycling. Sub-surface irrigation in greenhouses also requires fairly sophisticated, expensive equipment and management.

The essential pre-requisite for sub-irrigation are; the existence of a high water table or an impervious sub-soil above which an artificial water table can be created; highly permeable root zone soil with reasonably uniform texture permitting good lateral and upward movement of water; where and when irrigation water is scarce and costly; and soil should not have any salinity problem. However, its advantages include; soil water maintained at a suitable tension favorable for good plant growth and high yields; minimized evaporation from soil surface; very low cost of water application; and it can be used for soils having a low water holding capacity and a high infiltration rate where surface method cannot be adopted and the sprinkler irrigation is expensive [8].

The Food and Agriculture Organization of the United Nations estimated that agriculture accounts for 70% of all water consumption, compared to 20% for industry and 10% for domestic [9]. Critical need therefore exists to implement water conservation practices in agriculture and urgent need to create strategies based on science and technology for sustainable use of water, including technical, agronomic, and managerial improvements [10]. It also necessitates adopting agricultural innovations that can improve the efficient use of water by plant and offer the opportunity to improve soil productivity and mitigate climate-related risks. Thus, this work intends to develop a time-saving and cost-effective irrigation facility for peasants and urban vegetable production.

2. Materials and Methods

The materials used in this experiment include a full length of 10 cm diameter polyvinylchloride (PVC) pipes, 5 cm diameter PVC pipes, 10 cm diameter PVC caps, nylon net with mesh size 1 mm, 10 cm diameter PVC elbows, topgit glue, scissors, hacksaw, a long 5 cm diameter galvanized pipe (for making holes on pipes) and measuring tape (**Figures 1-4**).

The sub-irrigation facility was constructed using the following steps (**Figure 1** and **Figure 2**):

Figure 1. (a) 10 cm diameter Pipe at initial stage, (b) Marking of 5 cm diameter holes on the 10 cm diameter pipe at 15 cm interval with a hot 5 cm diameter galvanized iron pipe, (c) 10 cm diameter underground reservoir pipes perforated in definite spacing of 15 cm apart, (d) Marking and cutting of the capillary pipes (10 cm long and 5 cm diameter).

Figure 2. (a) Making of 3 - 4 mm holes round one end of each of the capillary pipes, (b) Fixing of the capillary pipes into the holes on 10 cm diameter pipes, (c) Installation of the constructed irrigation system, (d) Complete Sub-surface irrigation system on the experimental plot.

Figure 3. Smart irrigated wooden box of vegetable (*Celosia agentea*) at the balcony of the Department of Crop Production and Horticulture, Lagos State Polytechnic, Lagos, Nigeria.

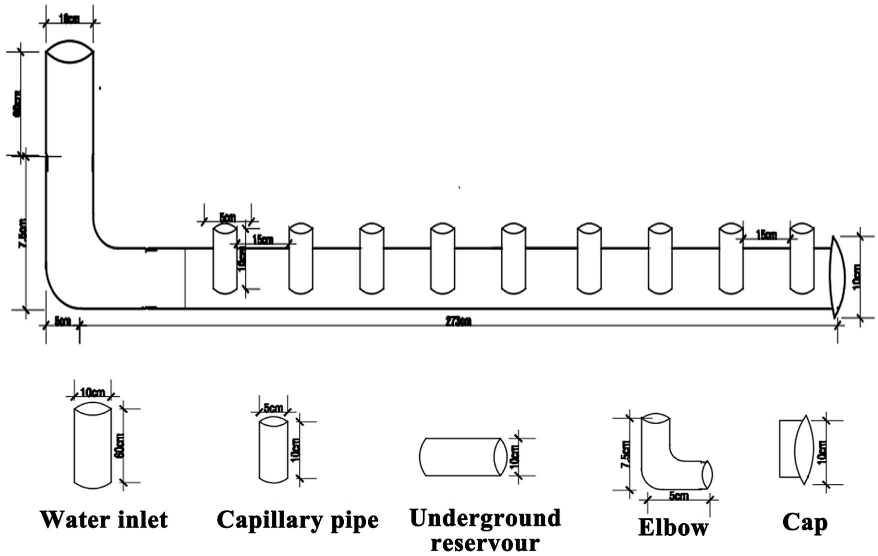

Figure 4. Schematic diagram of the Sub-surface irrigation system.

1) Marking and making of 5 cm holes at a spacing of 15 cm in between each hole on four 10 cm diameter pipes using a hot 5 cm diameter galvanized pipe for easy perforation.

2) Marking and cutting of 5 cm diameter PVC pipes into 10 cm length to be fixed into the holes created on the 10 cm diameter PVC pipes.

3) Making of a 3 - 4 mm holes round one end of the 10 cm long, 5 cm diameter pipes.

4) Cutting of nets into pieces sizeable enough to cover the other end of the small 10 cm long, 5 cm diameter pipes.

5) Cutting of another 60 cm long, 10 cm diameter pipes to serve as water inlets.

6) Coupling (with Topgit glue) of the perforated 270 cm long, 10 cm diameter pipe to the water inlet pipes (60 cm long), using the 10 cm diameter PVC elbow.

7) Fixing of 10 cm diameter cap at the other end of the perforated 270 cm long, 10 cm diameter pipes with glue.

8) Fixing of netted end of each 5 cm diameter, 10 cm long pipes (capillary pipes) into the holes made on the 10 cm diameter pipes at 15 cm intervals.

9) Excavation of soils in the middle of raised or sunken beds prepared for vegetable production to conveniently accommodate the constructed sub-surface irrigation kit.

10) Placement of the constructed sub-surface irrigation kits into the excavated portions of seed beds (one irrigation kit per bed) with the use of balancing/levelling plum.

11) Covering up of the inserted irrigation kit and filling up with water to capacity.

Working Principle

The sub-irrigation kit is made of sub surface PVC reservoir on which 10 cm long capillary pipes are inserted at 15 cm intervals with an adjoining inlet on one side, and a cover on the other side as seen in **Figure 1**. The 10 cm long capillary pipes are perforated at about 1 cm from one end of the pipe to accommodate about ten holes and the other end is covered with 1 mm mesh size nylon net to prevent soil passage and deposition in the buried PVC reservoir. The complete sub-irrigation kit is installed into levelled seed bed at 12 to 12.5 cm depth that ensures even distribution of water to the capillary pipes (**Figure 2(c)** & **Figure 2(d)**). As water is being supplied to the buried PVC reservoir through the inlet, it is thus made available by the 10 cm long capillary pipes through capillary action to the root zone of plants and soil surface.

3. Results and Discussion

The sub-irrigation kit could supply optimally 21.89 litres of water to a 1 m × 3 m seedbed between the spaces of two days and 5 days in a week or as may be required within the time frame of the season. This sub-irrigation facility eliminates the drudgery associated with other methods of supplementary water application and it is more time-management efficient and cost-effective (**Table 1**). The effects of conventional irrigation characteristics, such as crusting, saturated conditions of ponding water, and potential surface runoff (including soil erosion) are eliminated as purported by Reich *et al.* [11]. Water application is highly uniform and efficient as wetting occurs around the root zone and water typically moves out in all directions through capillary action. This smart subsurface irrigation design saves water and improves yields by eliminating surface water evaporation and reducing the incidence of weeds and disease (**Figure 3**). Water is applied directly to the root zone of the crop and not to the soil surface where most weed seeds germinate after cultivation. The additional heat provided by dry surface conditions may be of benefit to some crops species by producing more crop biomass, provided water is sufficient in the root zone. The design allows for fertigation; hence, water and fertilizer application efficiencies are enhanced, and labor needs are reduced (**Figure 3**).

Table 1. Cost implication of installing a 3 m by 1 m sub-surface irrigation kit.

S/No	Description	Unit price	No required	Amount (₦)
1	10 cm PVC pipes	1500	2	3000:00
2	5 cm PVC pipes	900	2	1800:00
3	10 cm Elbow	600	1	600:00
4	10 cm Cap	100	1	100:00
5	1 mm Nylon net	3000	1/8	375:00
5.	Topgit gum	600	1/12	50:00
7	Drilling of holes on 10 cm PVC pipes	2000/Manday	1/10	200:00
8	Drilling of holes on 5 cm PVC pipes	2000/Manday	1/5	400:00
	Total			6525:00

4. Conclusion and Recommendation

The construction of the irrigation system is simple and cost-effective. It is easy to use and requires little or no maintenance. Its simple construction makes it possible to be utilized in wooden or plastic boxes for the nursery and raising of vegetables crops in areas with limited or unavailable land space such as terraces, balcony and rooftop decking. It can also be used in open field especially where there is a shortage or inadequate water supply. Its advantage in water conservation makes it more efficient on the field where there is shortage or inadequate water supply. Its mechanism is based on the principle of soil water capillarity.

It is therefore recommended that this irrigation system be adapted for use to mitigate the effects of climate change.

Conflicts of Interest

The authors declare no conflicts of interest.

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