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Assessment of Water distribution Efficiency Using Solar Powered Drip Irrigation System Convenient for West Burkina Faso Small Scale Farming

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Abstract

In order to build the capacity of smallholder farmers, the appropriate scale mechanization consortium team in Burkina Faso designed and tested a small scale drip irrigation system for vegetable production. An experiment was conducted in Sonsongona village "11.2522°N, 4.4559°W" in the Houet Province of the Hauts-Bassins Region. The irrigation system consisted of four compartments: 1) Seven (07) meters depth well in which a submersible pump (ps2-200 h 07) 2) The pump was placed and connected to two electrically semi-automated solar panels (130 watts each) 3) Polytank water tower with a capacity of 2000 liters was feed up from the pump 4) Grid drip system on the irrigation plot. The experimental design was a randomized complete block. The system evaluation was based on measurements of water quantities emitted by 48 emitters per block as well as the flow rate of the pump and the water tower. The quantities of water collected from the emitters of the 4 valves therefore varied significantly. The lowest value (92.25 ml/7 minutes) was observed at the emitters of valve 8 and the highest (97.26 ml/7 min) at the emitters of valve 2. The 5th and 60th day after installation data showed similarity in term of the quantities of water emitted by the emitters of the 4 valves ($p > 0.05$). The daily operating peak flow of the pump was 1.10 m^3/h with an average water pumping rate of about 0.87 m^3/ h. The average flow delivered by the water tower was about 1.06 m^3/ hr. For crops production efficiency, the system was tested and the average yields were 14,750 ± 736 kg/ha of cabbage in a mulch plot compared to 8,500 ± 736 kg/ha in no-mulch plot. Onion yield was 4,187.50 ± 162.41 kg/ha with mulching compared to 1,750 ± 162.41 kg/ha without mulching. As for tomatoes, on straw plots, the yield was 6,875 ± 547.5 kg/ha compared to 3,975 ± 547.5 kg/ha on no-mulch plots. It could be concluded that, the current designed drip irrigation is functional and could be suitable in smallholder farming system and rural communities' use since it doesn't recommend much efforts for maintenance. It can be used to grow vegetables (20 square meters), livestock water drink and seed crops cultivation which could improve rural family livelihood and nutrition especially women and children.

Keywords: Drip irrigation system • Installation • Assessment • Solar panels • Agricultural production • Burkina Faso.

Introduction

Agriculture in the Sahel countries including Burkina Faso, plays an important role in economic and social development [1]. Agricultural contributes 35% of the GDP and employs 82% of the working population [2]. Burkina Faso has a great potential for arable land estimated at 9 million hectares (ha), of which 46% is currently being exploited. Irrigable land constitutes 233,500 ha, of which 12% is currently being farmed. In addition, the country has 500,000 ha of lowlands that can be easily managed. The potential for the development of irrigation is therefore huge. Burkina Faso's climate is characterized by two contrasting seasons: a rainy season and a dry season. Moreover, Burkina Faso's agriculture is mainly rainfed and therefore dependent on climatic conditions.

Traditional agricultural techniques are facing climate change in the form of reduced rainfall, warmer temperatures, desertification, etc. [3]. This climate variability over recent decades has shown the high vulnerability of production systems, resulting in significant impacts on crops and the living conditions of rural populations [4]. Thus, in all regions of the world where rainfall is insufficient to allow abundant and regular harvests, access to water for irrigation is an essential complement to all agricultural production [5]. Irrigation is undoubtedly the most important activity, as it contributes, on a global scale, to nearly 70% of freshwater withdrawals and more than 90% of water consumed, since a large proportion of the water withdrawn for this purpose is evaporated and transpired [5]. In Burkina Faso, water control strategies emerged with the droughts of the 1970s' to secure and improve agricultural production [4]. Efforts have been focused not only on irrigation downstream of small dams but also on the development of water and soil conservation programs. In 1993, the total area under total water control was estimated at 14,600 ha, including 10,600 ha developed by the government and about 4,000 ha developed on the basis of private initiatives. The areas currently being developed are around 6,000 ha of lowlands in agriculture with partial water control, while the country has 233,500 ha of irrigable land [6]. The constraints related to water management in agricultural environments are of various kinds in the country: material, technical and financial. Some of the water-related challenges that small-scale farmers face are:

- The high cost of the investment
- The lack of qualified human resources in the handling of equipment after installation (sprinkling and drip irrigation)
- The poor organization of the irrigators already installed on the developed perimeters

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- The drop in water levels in the reservoirs
- The poor management and lack of maintenance of the facilities

For better water management, three irrigation techniques, including surface irrigation, sprinkler irrigation and drip irrigation, are commonly used, especially in arid areas [7-9]. Among those three methods, the drip irrigation system is the most water efficient. Indeed, the drip irrigation is a water management technique that makes it possible to produce in the dry season, to increase and intensify agricultural production against food shortage and malnutrition [10]. This system is an effective tool to achieve the combined goals of sustainable water use, food security and poverty alleviation in the developing world [11]. In sub-Saharan Africa, deployment of the drip irrigation system targeted mainly smallholder producers [12]. Many smallholder drip irrigation systems have been promoted several years ago by NGOs in eleven West African countries including Benin, Burkina Faso, Cape Verde, Chad, Gambia, Ghana, Guinea Bissau, Mali, Mauritania, Niger, and Senegal. However, the technology has been successful in some locations and unsuccessful in others [11]. The facilities that are still operational are those mainly used by pilot farmers for experimental or demonstration purpose. The existing systems in place are typically privately owned [13] rather than community-scale drip irrigation. Solar-powered drip irrigation has proven to be cost effective compared to alternative technologies [14]. For a successful dissemination of the technology, the support of the stakeholders and their ability to use and maintain the system must be strengthened. In that regard and in order to promote the intensification of agricultural production in Burkina Faso at any time of the year, this study aims to design, implement, evaluate and test a drip irrigation system for vegetable production by using solar pumps.

Material and Methods

Experimental site description

The experiment was carried out in Sonsongona's village 24 km from the city of Bobo-Dioulasso (11.2522°N, 4.4559°W). The study area belongs to the sub-Sudanese climate with an annual rainfall between 800 mm and 1200 mm (Figure 1). The rainfall is characterized by a very high spatial and temporal variability. The area has natural wooded savannah vegetation divided into three strata: tree, shrub and herbaceous. The tree-strata include species such as *Vittelaria paradoxa* C. F. Gaertn and *Parkia biglobosa* (Jacq.) R. Br. The arbustive stratum consists of Combretaceae and species such as *Piliostigma thonningii* (Schumach.) Milne-Redh, *Piliostigma reticulatum* (DC.) Hochst and *Daniellia oliveri* (Rolfe) Hutch & Dalziel, 1928. The herbaceous stratum is mainly dominated by the following species: *Andropogon gayanus Kunth*, 1833 and *Crotalaria retusa* Linnaeus, 1753. In addition to the natural vegetation, there are tree plantations such as *Eucalyptus camaldulensis Dehnh*., 1832, *Gmelina arborea Roxb*. Ex Sm.1810 and *Tecnona grandis L.f.* 1782. The study's zone is characterized by soils mainly of the tropical ferruginous type. Those soils are of variable texture, generally with a sandy tendency in the surface horizons, and clayey in the deeper horizons (> 40 cm).

Design of drip irrigation and inherent equipment

The experimental area before the installation of the irrigation kit was first ploughed (15 cm depth). After manual crushing of the clods, the ground

Figure 1. Geographical location of the study site.

Figure 2. Technical equipment used for the implementation of the installations of the drip irrigation system: **2a)** Gutter tube **2b)** PE tube **2c)** PVC tube inside the trench before burring **2d)** T-PVC, **2e)** Strainer filter **2f)** Yarn doll **2g)** Flowmeter **2h)** Solar panels **2i)** Glue box **2j)** Stopper **2k)** Junctions **2l)** Pum **2m)** Male elbow **2n)** Regulator **2o)** Female elbow **2p)** Valve.

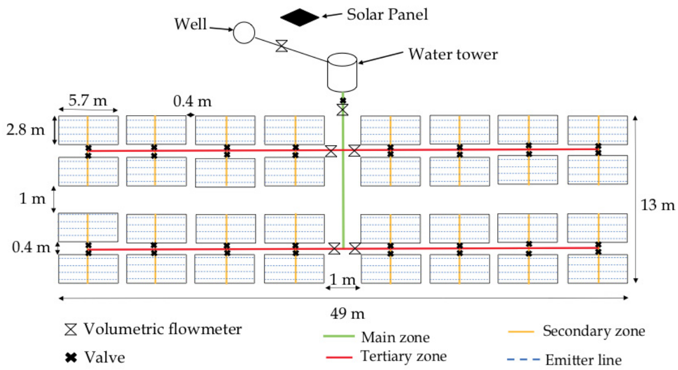

Figure 3. Fully randomized Fisher block experimental design used during the experiment.

was levelled before establishing the site. For this task, the equipment used consisted mainly of tape, ropes and stakes. Delimitation was made using stakes for field, blocks and split-plots. The experiment was conducted in a field where the cultural history was fallow rice. The area was 637 m² (49 m × 13 m) and the individual plots were 15.96 m² (5.7 m × 2.8 m) each (Figure 2). The experimental design was made of randomized complete block with 08 treatments and 04 replications. The elementary plots were separated by 0.4 m alley and the replicates by 1 m alleys. For irrigation system, 05 trenches 0.3 m wide and 0.5 m deep have been built to bury PVC pipes. Indeed, a 13 m main trench built, resulting in a total of 186.2 m of trench. Subsequently, 33 valves were installed, including one valve per plot and one on the main line between the water tower and the blocks of plots (Figure 3).

Stepwise installation of the irrigation system

The installation of the drip irrigation system was done in four steps: 1) the construction of the well, 2) the installation of the polytank, 3) the installation of the irrigation kits and 4) the installation of the pump and its accessories. The well was near the experimental plots precisely 5 m away. The well was 7 m deep with a diameter of 1.2 m. A 2000-litre polytank water tower was used. This water tower was placed on a 2 m high metal support. A footing was fixed in a 1 m² hole with cement, stones, gravel and sand. A week later, a support was fixed to the base using screws. After the water tower was mounted, a metal cap was screwed onto the bracket to protect the polytank from the sun bit (Figure 4B). The elevated water tower was created the pressure applied to the entire system. The pipe's installation was carried out in eight steps: 1) The construction of trenches 0.3 m wide and 0.5 m deep, 2) The installation of PVC tubes in the trenches, 3) The assembly and installation of valves and flowmeters, 4) The cutting and installation of polyethylene tubes, 5) Perforating the polyethylene tubes, 6) installing the junctions on the polyethylene tubes, 7) Cutting and connecting the emitter lines and 8) Straightening and fixing the emitter lines to strings (Figure 4A). The pump used to pump the water up is a PS200 (PS2-150 HR 07 LORENTZ Germany). The installation of the pump and its accessories was done in five steps: 1) The assembly and installation of the pump support, 2) The assembly and installation of the solar panel support, 3) The assembly of the pump accessories and wiring, 4) The immersion and connection of the pump to the solar panels, 5) The pumping test. After installation, the solar collector in a fixed position facing the direction of 180° south. No obstructions block the sun at any time of the day. The solar collector is set so the angle of incidence is near zero at solar noon (between 12:00 p.m and 12:45 p.m) (Figure 4).

Data collection and statistical analyses

The determination of crop water requirements was done using CLIMWAT 2.0 for CROPWAT and CROPWAT 8.0 software. First, Bobo - Dioulasso's climate data, collected at the airport, were searched in CLIMAWAT and then exported to CROPWAT. Bio-climatic, soil and crop parameters were integrated into CLIMWAT 2.0 for CROPWAT and CROPWAT 8.0 software. The standard CLIMWAT data were used to calculate the water requirements of crops using CROPWAT. The vegetables water requirements were 64.04 m^3/decade/ha, 61.24 m^3/decade/ha, 56.56 m^3/decade/ha and 57.52 m^3/decade/ha respectively for onions, cabbage, tomatoes and green beans. These water requirements were generated per decade (10 days). To match the vegetables water requirements, the flow rate and crop requirements have been taken into account in order to properly fill the polytank. Water volumes at the valves were measured using 180 ml graduated cylinders to collect water from the emitters during 07 minutes of irrigation. This collection time was determined as an approximate time to collect 100 ml of water. The measurements were made first by zones, i.e. during the irrigation of a single block. Then a second measurement was made on the same emitters but while all the zones were irrigating. These measures concerned 04 valves per zone. Considering the high number of emitters, the measurements were made on 12 emitters per valve distributed over 04 emitter lines, including 03 emitters per line, namely the 2nd, 5th and 8th emitters (Figure 5). In total, all these measurements were carried out on 1152 emitters. The procedure included 1) Filling the water tower, 2) Cleaning the filter with a brush, 3) Digging a hole about 15 cm deep under the emitter concerned, 4) Placing the 180 ml bottles in the dug holes, 5) Opening the valves of a single zone for zone collection or all valves for general irrigation collection, 6) Timing of 7 minutes, 7) Closing the main valve after 7 minutes of irrigation, 8) Repeated the process for all emitters.

The evaluation of the variation in water quantity over time was carried out over three different periods during the operation of the system. It consisted in measuring the volumes of water collected as a function of the system's operating time. The first water volume collection was performed just after

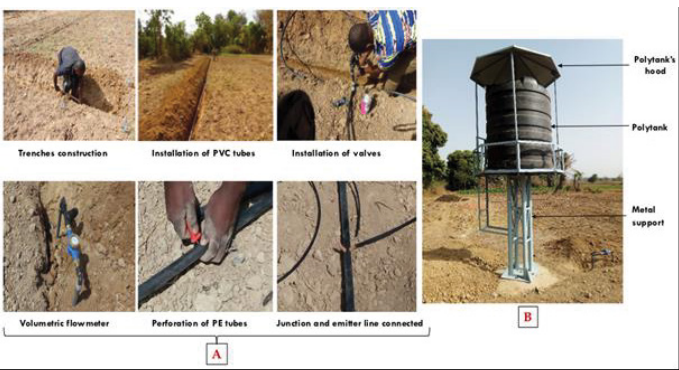

Figure 4. 4a) Installation of drip irrigation kits **4b)** Presentation of the tower after its installation.

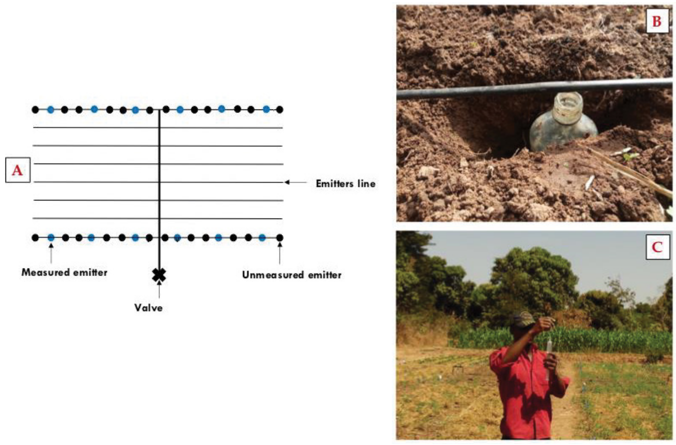

Figure 5. Water collection method **5a)** Design to collect data layout **5b)** Bottle in the under the emitters to collect water **5c)** Reading the water quantity collected in the Graduated cylinder and measurement of water quantities.

installation (5 days), then the second, one month later (30 days) and the third, two months after installation of the system (60 days). For the pump evaluation, the pump start time and shutdown time were recorded. In order to achieve this, the pump was left running from the day before to the next day, but care was taken to record the start time of the water pumping. After irrigation, the pump was shut down and started at 16 hours (4 PM) and the time of shutdown was also noted once the pump stopped pumping water up. In addition, the hourly flow rate of the pump as a function of the hourly time was evaluated. The flow delivered by the water tower was evaluated through the main volumetric flowmeter installed at the head end of the network, over 10 hours of operation of the system. The evaluation method consisted of: 1) fill the water tower with water, 2) read the main flowmeter number, 3) open the main water valve, 4) note the valve opening time, 5) read the new flowmeter number every one hour, 6) calculate the hourly flow (liter/hour).

All the measurements made were previously entered using the Excel 2013 spreadsheet and then analyzed using XLSTAT 2014.5.03 software. This software made it possible to perform descriptive analyses of the data and analysis of variance. The separation of the means was done by the Student t-test and the Newman Keuls test at the 5% threshold as suggested by [15]. Therefore, this test allows comparing with all pairs of means by controlling the overall alpha risk.

Results

Homogeneity of distributed water

The irrigation system was effectively installed over an area of 637 m^2. It consists of a water source (the well) equipped with a solar pump, a solar installation, a water storage source after rising, an irrigation kit device installed on the experimental plot (Figure 6). The homogeneity of water distribution in relation to the emitters per valve are presented in Table 1 for the operation of a partial zone versus the operation of the entire system (all zones open). The quantities of water collected by the emitters of the valves concerned, from the 30th day after the installation of the system, were significantly different. The quantities of water collected from the emitters of the 4 valves therefore varied significantly. The lowest value (92.25 ml/7 minutes) was observed at the emitters of valve 8 and the highest (97.26 ml/7 minutes) at the emitters of valve 2. The 5th and 60th day after installation data showed similarity in term of the quantities of water emitted by the emitters of the 4 valves ($p > 0.05$). The quantities of water collected during the operating period of all zones did not vary significantly from one emitter to another for the three collection periods attesting the homogeneity of water distribution by valve (Figure 6 and Table 1).

Variation of water quantity overtime

Quantities of water according to the collection period, when operating a single

Figure 6. Different components of the drip irrigation system **6a)** Solar pump immersed in the well **6b)** Solar installation **6c)** Water storage device **6d)** Irrigation kit device.

Table 1. Quantity of water (ml/7 minutes) collected at the emitters per valve operating over a single zone and over all zones.

Watering area		E2	E7	E1	E8	Significance
With only one zone	Q5d	100.99^{a}	99.91^{a}	97.83^{a}	94.94^{a}	NS
	Q30d	97.26^{a}	97.05^{a}	94.14^{ab}	92.25^{b}	*
	Q60d	93.05^{a}	91.85^{a}	90.67^{a}	87.94^{a}	NS
Over all zones	Q5d	49.35^{a}	50.63^{a}	38.65^{a}	46.95^{a}	NS
	Q30d	45.48^{a}	45.29^{a}	36.27^{a}	43.92^{a}	NS
	Q60d	41.75^{a}	40.55^{a}	32.93^{a}	39.58^{a}	NS

Q5d: Quantity of water collected on the 5th day after installation; Q30d: Quantity of water collected on the 30th day after installation; Q60j: Quantity of water collected on the 60th day after installation; E1: Emitters 1; E2: Emitters 2; E7: Emitters 7; E8 : Emitters 8; * : $p < 0.05$; NS: Not Significant; Values followed by the same letter on the same row are not significantly different at the 5% threshold.

Table 2. Variation of the water quantity (ml/7 minutes) of the emitters per valve as a function of time for (i) a zone in operation and (ii) all valve in operation.

Water quantity		CP1	CP2	CP3	Significance
With only one zone	WQE1	97.83^{a}	94.14^{a}	90.67^{a}	NS
	WQE2	100.99^{a}	97.26^{ab}	93.05^{b}	**
	WQE7	99.91^{a}	97.05^{b}	91.85^{c}	***
	WQE8	94.94^{a}	92.25^{a}	87.94^{a}	NS
Over all zones	WQE1	38.65^{a}	36.27^{a}	32.93^{a}	NS
	WQE2	49.35^{a}	45.48^{a}	41.75^{a}	NS
	WQE7	50.63^{a}	45.29^{a}	40.55^{a}	NS
	WQE8	46.95^{a}	43.92^{a}	39.58^{a}	NS

CP1 : Collecting Period 1 (5th day after installation); CP2: Collecting period 2 (30th day after installation); P3: Collecting period 3 (60th day after installation); WQE1 : Water quantity of the valve 1's emitters; WQE2 : Water quantity of the valve 2's emitters; WQE7 : Water quantity of the valve 7's emitters; WQE8 : Water quantity of the valve 8's emitters; NS: Not Significant; ** : $p < 0,01$; *** : $p < 0,001$; Values followed by the same letter on the same row are not significantly different at the 5% threshold

zone, is presented in Table 2. The emitters of valves 1 and 8 were similar at a threshold of 5% for the three collection periods. On the other hand, highly significant differences were observed between the emitters of valves 2 and 7. Also, the lowest values collected are observed on the 60th day after installation and are 93.05 ml/7 minutes and 91.85 ml/7 minutes respectively for valves 2 and 7. The high values collected were observed for both valves (2 and 7) on the 5th day after installation of the system and were 101 ml/7 minutes and 104 ml/7 minutes respectively. In addition, a gradual over time decrease in values is observed overall. When all the zones are in operation, at the emitters of the four valves, no significant difference was observed between the collected values. However, a decreasing evolution of the values was also observed during the experiment (Table 2).

Running of the pump

Figure 7 (A and B) shows the respective evolution of the pump start and stop times over a period of 18 days. In general, the pump would automatically start around 7:00 a.m. and stop operating at around 5:00 p.m. The pump start graph shows a decreasing rate over the 18 days. It shows that the pump started on the 18th day at 7:05 a.m., i.e. earlier than the days previously recorded. On the 2nd and 3rd day, the pump started at the same time (7:38 a.m.) corresponding to the day when the start was the latest. However, the average start time was 7:21 a.m. With regard to shutdown times, Figure 7 (B) shows that on the 6th day, the pump shut down before 5 p.m. and more precisely at 4:46 p.m. The other shutdowns were made after 5 p.m., which gives an average shutdown

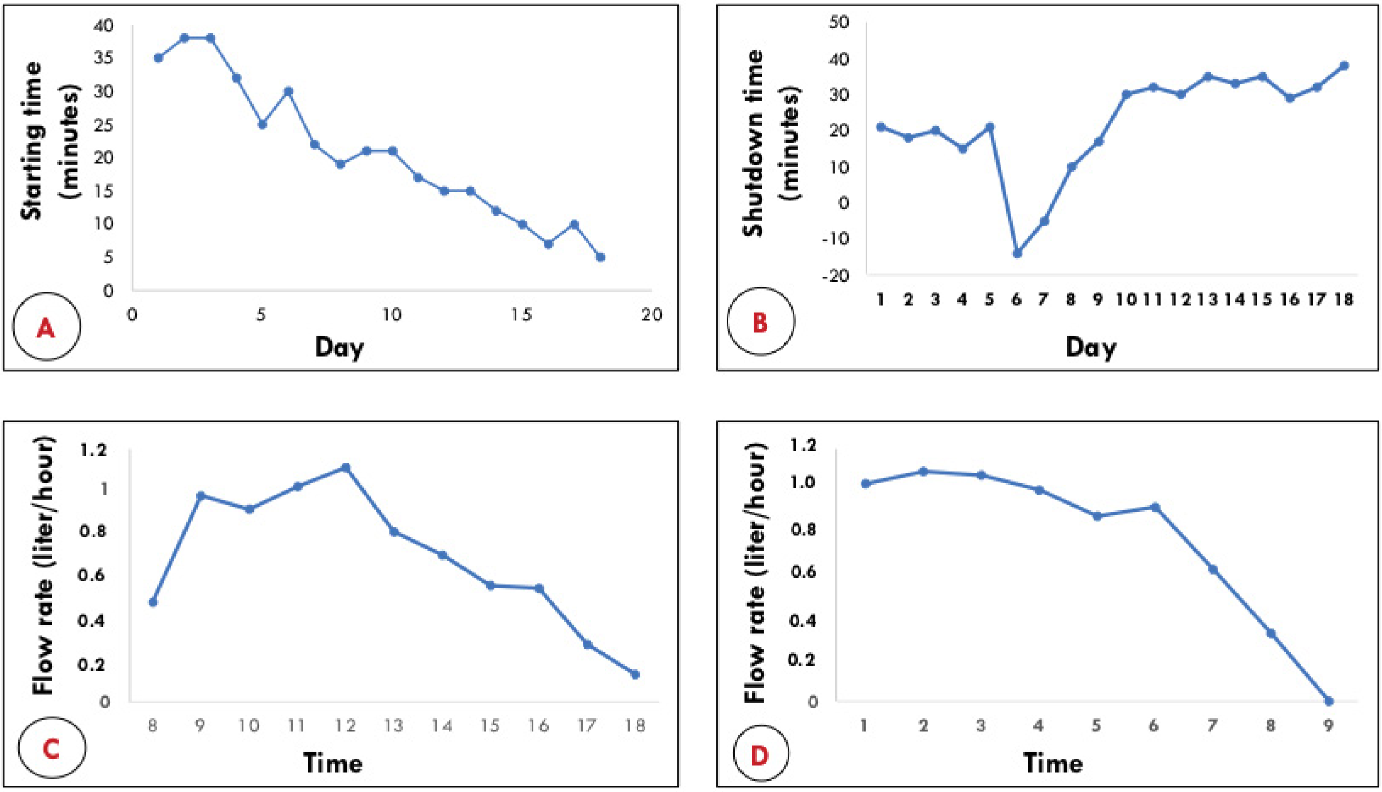

Figure 7. 7a) Evolution graph of the hours of automatic starts of the pump 7b) Automatic stops of operation of the pump 7c) Evolution of the pump flow rate over a pumping day 7d) Evolution of the flow rate of the water tower

time of 5:22 p.m. The daily operating results of the PS-2 200 HR 07 pump are shown in (Figure 7) (C). The peak flow (1.10 m^3/h) was observed around 00:00 p.m. and the lowest value (0.13 m^3/h) after 5:00 p.m. The figure's shows the solar radiation. However, the amount of water pumped up did not exceed the daily needs of the operation. On the Figure 7 (D), information on the status of the evolution of the hourly flow rate of the water tower is shown. The figure 7 shows a generally downward trend although it is in three phases. The first phase, which is downward, is characterized by a slightly arched shape and lasts five (05) hours. It illustrates the highest flow value of 1.056 m^3/h. On the other hands, the second part of the figure 7 is bullish and lasts only 01 h. As for the third and last phase of the figure, it shows a downward line over 3 hours of time. This phase has the lowest flow rate value of 0.001 m^3/h. However, the average flow of the water tower over the 10 hrs is 1.062 m3/h (Figure 7).

Agronomic efficiency of the drip irrigation system and evaluation of the usefulness of mulching

At the end of the experiment, the weed growth rate was 629 ± 8.47 g of dry matter. The application of mulching (5 kg/m^2) reduces grass cover while increasing vegetative growth and yield. The average yields were 14,750 ± 736 kg/ha of cabbage in a mulch plot compared to 8,500 ± 736 kg/ha in no-mulch plot. Onion yield was 4,187.5 ± 162.41 kg/ha with mulching compared to 1,750 ± 162.41 kg/ha without mulching. As for tomatoes, on straw plots, the yield was 6,875 ± 547.5 kg/ha compared to 3,975 ± 547.5 kg/ha on no-mulch plots. The mulching operation increases the yield by reducing the surface evaporation water loss and by increasing the water use efficiency.

Discussion

The Assessment of the homogeneity of water distribution by the emitters of the valves revealed significant variations in the quantity of water collected on the 30th day after installation of the drip irrigation system for per-zone collection. These variations can be explained by a slight obstruction (clogging) of the emitters following the hoeing for weed control. These hoeing were involved in disconnection of some emitter lines. In addition, there were cases of leakage observed during this period on some zones. These results were as predicted by the manufacturer 'NETAFIM' emitters used, which stipulated that the pH of the water, impurities, fertilizer concentration or certain technical characteristics of the system led to the creation of deposits, leading to total or partial clogging of the emitters. Also, AZUD (manufacturer), the total or partial obstruction of the emitters affects the uniformity of water application and reduces the efficiency of the system. Studies conducted in the Jordan Valley (Israel) on drip systems have shown that two factors contribute to the clogging of the system: the lack of preventive maintenance and the existence of operating errors [16-19]. Hence, regular maintenance and calibration of the drip system is needed. The smallest quantity of water at the emitters of valve 8 and the pressure-loss were due to the distance and lateral position from the water tower and especially in addition to the branching effect of the pipe system. These results corroborate those of [20], who found that the pressure decreases were caused by the strainer, control valve, branch bends, different connections and finally the boom carrier itself when evaluating the performance of an irrigation kit. On the other hands, [21] found that topography and field length have an effect on water distribution uniformity. They concluded that the steeper and longer the field, the more likely it was that the lower part of the field would receive more water with a difference in irrigation time of up to 30% for a slope of only 2%. The appropriate design and calibration of the system is important for uniform water distribution.

The study showed that the amount of water collected per valve does not vary over the three assessment periods (5th, 30th and 60th days) of follow-up. The system therefore did not have major operating deficits leading to preventive maintenance. However, the gradual decrease in the quantity observed may be explained by deposits or leaks observed. in addition, it was noticed the effect of water evaporation during certain measurements following the increase in temperature, even if this has not been verified, it can be a source of variation since the collection time is reduced. Consequently, the production level decreases, with an increase in the return time on investment and operating costs. The mulching technique increases the water use efficiency. In addition, storage of energy in the battery can further improve water uniformity in cloudy condition.

Installed pump showed that the automatic start is performed around 7:21 a.m. and the shutdown at 5:22 p.m., which corresponds to an approximate daily operating time of 10 hours when not voluntarily shut down. The observed flow variations could be explained by the variation in pump power. It is induced by a variation in solar intensity on solar modules due to a decrease or increase in solar radiation related to the presence or absence of clouds or simply due to a deposit of dust on solar panels. Also, [22], who found that the passage of a few clouds disrupted the functioning of solar panels throughout the day. The presence of clouds affected the functioning of solar panels. They reduced the efficiency of the panels. In fact, the amount of energy produced by solar panels is directly related to the solar radiation of the location and exposure to the sun's rays. Clearer the sky is, more powerful the panels are and more efficient they are. However, even if the sky is cloudy and the light shines on the ground, the panels can still produce nearly half of their performance. For a completely cloudy sky, the panels will be unproductive. Another study also stated that irrigation through solar pumping is self-regulatory, as solar radiation is the driving force behind both solar pumping and crop evapotranspiration [23]. In addition, [24] noted that the major remaining disadvantage for solar modules was the accumulation of dust on the glass plates making up these panels, thus considerably affecting their efficiency. Dust deposits on solar modules greatly reduced the maximum power by 77% and 18% respectively for monocrystalline and polycrystalline modules [25]. Also, studies carried out in Egypt showed that this maximum power reduction due to dust could reach 35% after only two months without cleaning the photovoltaic modules [26].

In this study, the crop requirements were determined on the basis of evapotranspiration, soil parameters and crop parameters. The water quantity to be filled into the polytank has been determined taking into account crop needs and water flow. Thus, the watering was done successively for each vegetable, taking into account its water needs. The variation in the flow rate of the water tower observed during the test is explained by the decrease in the water level in the tower or by the decrease in the waterfall height. This variation resulted in a decrease in the hourly quantity of water recorded following a decrease in the rate of water exit. [27] explained the variation in fluid velocity by two parameters, namely fluid height (h) and gravity acceleration (g): $v^2 = 2g \times h$. According to the author, the height of the liquid, the higher is the ejection velocity, and inversely the lower the height, the lower is the ejection of the velocity.

Conclusion

This study was initiated to contribute to the improvement of livelihood and resilience of smallholder farmers through off-season production by drip irrigation. The data collected from the pump sustained that its operation is more dependent on sunlight. However, storage battery can further improve water uniformity in cloudy condition. The pump starts functioning around 7 a.m. and stops around 5 p.m. Overall, the irrigation system installed is functional and therefore allows the production of off-season vegetables without any major concern for functionality, apart from leaks and disconnections from the emitter lines observed. It is therefore possible to design a drip irrigation system at the small scale for the household farm around a well in an area where the depth of the water table does not exceed 20 meters deep. But this requires a good understanding of different parameters of the drip irrigation system. Thus, well-controlled irrigation is a means that can be used to combat undernourishment and enhance food security. The system's management itself is conditioned by cropping period, quantities of water to be supplied (60-65/decade), periods of water supply, area to be watered per day, and this until the maintenance of the system and the crops. Maintenance and calibration activities include filter cleaning, leak repair and circuit purging. Even though, that system is ready for scaling in smallholder farming system, further study on mulching effect (moisture, weed control) in irrigated area worth to be investigated.

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Conflict of Interest

Authors must clearly disclose commercial associations that might create a conflict of interest in connection with submitted manuscripts and must give credit to any ghostwriters involved in the writing of the manuscript. This statement should include appropriate informations for each author, thereby representing that competing financial interests of all authors have been appropriately disclosed.

Appendix

Authors can share all the supplementary information that they could not share in the manuscript as appendix. Appendix also carries questionnaires, guidelines, and the universal standards followed in conducting studies involving animals.

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