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Drop-by-Drop Irrigation Technology Powered by Photovoltaic Solar Panels

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Abstract:

Drop-by-drop irrigation is an optimal technique of localized watering which permits the normal development of a plant with minimal water necessary for its good growth. Its aim is to minimize water wastage and promote agriculture in arid zones. The present study was on a drop-by-drop irrigation device powered by solar energy which provided its own electrical energy. This system was experimented in the culture of Vernonia amygdalina (Delile) also known as “Ndolé” in Cameroon. This was in a bit to contribute to development and in the promotion of “clean and new generation” agriculture.

Keywords — **Arid zones, clean agriculture, irrigation, solar energy, wastage.**

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I. INTRODUCTION

Vernonia amygdalina Delile, also known as "ndolè" in Cameroon, is a plant present in most African countries, from Guinea to Somalia, south to northeast of South Africa, and also Yemen. It is a ramified shrub with a maximum height of 10 m, a trunk less than 40 cm in diameter and a smooth, gray and cracking bark. Its leaves are alternating and simple, its glandular fruits (1,5 - 3,5 mm long) are covered with long pappus silks. This plant is being domesticated in Cameroon and is grown as a vegetable [1] in various vegetable farming basins in urban and peri-urban areas. In order to master its culture and increase its production, a drop-by-drop irrigation system was experimented in an arid zone (on the hill of the Institute of Agricultural Research for Development, IRAD).

This drop-by-drop irrigation system consists of a water supply located at the root of the plant which flows continuously at a low speed (1 – 4 l/h) and at a low pressure. This system reduces water consumption by 50 to 70% compared to gravitational irrigation and watering thereby minimizes losses due to absorption and water infiltration. With the use of fertilizers, this system contributes to the improvement of the quality of the products and increase production by 20 to 40%.

II. MATERIALS AND METHODS

- ***Physical materials***

In order to setup the studied nursery, wheelbarrows, shovels, picks, germination bags or containers, manure etc. were needed.

- ***Biological material***

It consisted of Vernonia amygdalina cuttings harvested at the campus of the University of Yaoundé I (3^o 46 ‘60’’ N and 11^o 31’ 60’’ E).

- ***Study area***

The study of the culture of this crop in arid zone using a drop-by-drop irrigation apparatus powered by solar energy was carried out in the experimental plots of FODEC (full name) found within the campus of the Institute of Agricultural Research for Development (IRAD) at Nkolbisson, located between latitude North 3^o45’ ($3{,}75^o$) and 4^o00’

(4,00°) and longitude East (Cameroon) 11°20' (11,33°) and 11°35' (11,67°).

The vegetation cover here was dominated by a herbaceous plant of the Poaceae family. This vegetation characteristic of anthropogenic disturbance is derived from a forest landscape.

The experimental plot consisted of three blocks of 278m^2 surface area of 41 planks which were 5m long and 1m wide, separated by furrows of 1m wide having a 207m^2 of seedbed. Each plank carried 10,000 plants inside 5 cm diameter containers placed side by side. The substrate was made of black soil rich in humus, mixed with sand in the proportions 2:1 [1](Fig. 1).

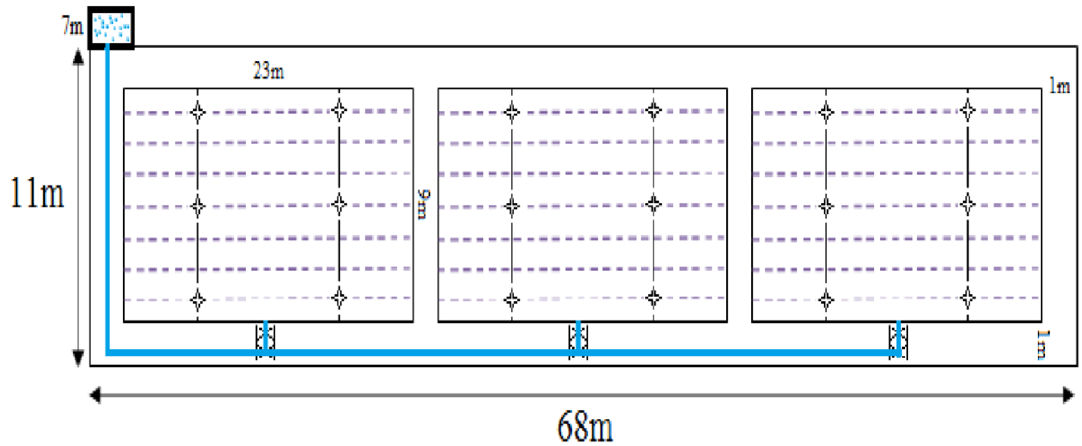

Fig. 1. Experimental setup of nursery

III. MECHANIZATION OF THE IRRIGATION SYSTEM

The drop-by-drop irrigation system designed for this purpose was set up. It was composed of elements that ensure and control the transport of water from the water source to the roots of the plants. The characteristic features of this system were:

A photovoltaic solar panel that produced DC electric current that was transformed into alternating current through a converter that delivers a 220 V voltage to power the submersible pump (Fig. 2). A battery that allowed the energy received from the generator to be stored in chemical form and was returned as a direct current according to the needs of the electrical equipment (Fig. 2). A switch which provided a manual control of the opening and closing of the electrical circuit. The latter was associated with a fuse or a circuit-breaker which provided its protection. A converter used to generate voltages and alternating currents from an electrical voltage source or of different frequency: it was the electronic power device (Fig. 2). A meter was used to measure the amount of electrical energy consumed by the submersible pump. This energy was given in "Kwh", although the legal unit is in "joule". The submersible pump allowed automatic watering. It was associated with a "suppressor" tank which stabilized the frequency of functioning, regulating speed flow and pressure as required. It ensured a low pressure at the level of the drippers (0.5 to 1 kg / cm, or even 5 to 10 m of water column). The reservoir, which was fixed at a height of 7 to 8 meters from the ground, made it possible to store water after pumping, the reserve thus constituted operated independently thereafter and the pump was re-launched only when this reserve was exhausted. For maximum use of the tank, it must be protected against algae and microorganisms which develop on its walls by disinfecting it with bleaching agent and taking into account the pressure drops from 200 to 300 gr in the filter (Fig. 2). The pressure regulator ensured an inlet pressure by means of a spring-loaded valve or any other mechanical system. A pressure gauge was used to check the correct functioning of the system.

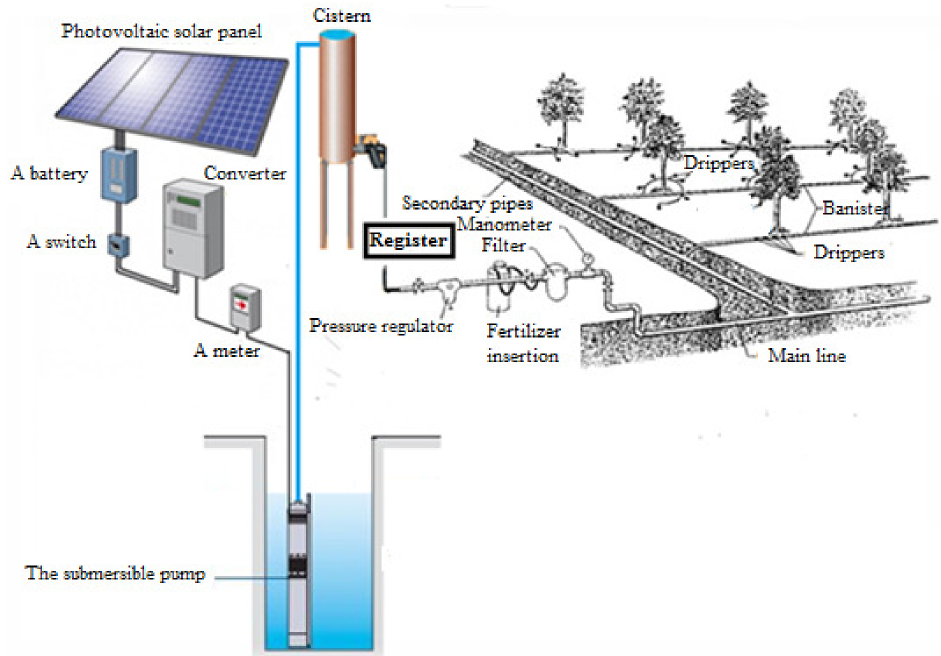

Fig. 2. Diagram of the drop-by-drop irrigation system

A sand filter (in the case of stored water or reservoir) and a sieve filter made it possible to eliminate the inert particles which may block the drippers. The quality of the filtering depended on the type of dripper. The main line ensured the flow of water from the filter outlet to the secondary pipes. These pipes ensured the circulation of water to the entrance of the plots to be irrigated and feed the tubes drop by drop. The diameter of these pipes must be large enough to avoid large variations in pressure between the various tertiary tubes (drop-by-drop tubes) and were determined as a function of the flow rate and the length. The drop-by-drop tubes were attached to a secondary tube by a joint which allowed the water to be brought to the root of each plant. Watering was ensured by drippers inserted at regular distances (cm or m) into the pipe. The essential characteristics were: the gapping of drippers, the nominal flow of these tubes at a given pressure and the homogeneity required for this flow rate between the beginning and the end of the tube. To these parameters defined by the crop, the length and slope of the land was added if it existed to calculate the diameter of the tube. The longer the pipes, the greater the pressure drop (Fig. 2). For a tertiary pipe of 16 mm and 5 drippers per linear meter, the maximum length on flat ground did not exceed 100 m (by giving itself a tolerance of homogeneity of the flows to drippers of 85 percent). On the other hand, a pipe of 22 mm and a spacing between the drippers of 60 cm, the length can exceed 300 m (with the same tolerance). Finally the drippers were perforated with fine capillaries or short nozzles grafted onto the tertiary pipe. Recent models are sophisticated and can only be repaid over 8 or 9 years. To do this, scrupulous care, maintenance and careful handling must be exercised in order to guarantee a long life (Figure the dripper always consisted of three elements: a microfilter followed by a zigzag system of pressure reduction and then an outlet chamber). The quality of a dripper depends on its low sensitivity to obstruction and on the homogeneity of its flow even in case of a small pressure variation.

IV. REQUIREMENT OF CULTURE

The ideal condition for the development of Vernonia amygdalina Delile is climate. V. amygdalina Delile is mainly cultivated in the equatorial zone; the nature of the soil, the characteristics of the soil will determine the frequency of watering. The drop-by-drop system, thanks to the precision of its control, is more effective in difficult situations than other irrigation systems. It is particularly suitable for sandy soils where percolation losses are high; the amount of water, the efficiency of drop-by-drop irrigation is 90-95% against 50-65% at the skate. The extension of this crop in arid zones requires a significant water supply. Thanks to the present irrigation technique presented above, V. amygdalina can be grown anywhere regardless of seasons (North of Cameroon) thereby increasing income of the farmers that are interested in its culture be it in urban or rural zones.

- **Determination of the amount of water required for the cultivation of Vernonia amygdalina**

The drop-by-drop system can be adapted to different water qualities like geothermal water that can be treated beforehand, but this requires filters well suited for the physical and biological quality of this water and especially a careful maintenance of all equipment. The technique can withstand a certain content of salt or limestone depending on the type of cultivars. The parameters for determining the optimal amount of water required for a good plant growth are:

- The nature of the soil (it is advisable to water 2 to 3 per day on a sandy soil and water once on a clay soil);
- The climate (heat wave, drying winds ...), the water reserves of the soil, the slope of the soil and the stage of growth of the plant.

For the experimental nursery of 748 m^2, 5 containers were used and the plot divided into three blocks containing several sectioned seedbeds. A seedbed of surface area(S) 207 m^2, a monthly evaporation rate of water E = 0.2 m and a rate of water loss (T) of 1.3 were considered.

Water volume needed by the plants in a month was calculated as follows: $V_m = S \cdot E \cdot T$

i.e. $V_m = 53{,}82m^3 \,/\, month$

Thus for a month of 30 days, a daily water volume (Vj) of 1.794m3 / day shall be consumed by the plants. With 2000 plants / m^2 of seedbed, a total of 414000 plants were obtained for the plot of 207m^2. A *V. amygdalina* required a daily water quantity $= 4{,}35 \cdot 10^{-6}\, m^3 \,/\, day$.

V. MAINTENANCE AND PRECAUTIONS

Regular maintenance of the elements of the network was carried out from the beginning to the end of the cultivation. This was done in order to avoid difficulties associated with clogging of the distributors. Clogging is associated with the quality and origin of water. Generally, there are two sources of water: surface waters that contain algae, bacteria and fine particles and groundwater very often loaded with sand or bicarbonate ions.

The analysis of water made it possible to determine the potential risks of clogging. One distinguished biological clogging caused by algae, bacteria and fungi. Physical clogging caused by the presence of deposits of fine particles, sand, silt or clay and other foreign bodies and chemical clogging caused by the precipitation of limestone, cementing silt or clay. The instructions for the maintenance of certain elements of the device are summarized in the table below:

TABLE 1
THE INSTRUCTIONS FOR THE MAINTENANCE OF CERTAIN ELEMENTS OF THE DEVICE

Elements	Instructions	Risks	Solution
Pressure gauge	Assure that the pressure is always> 3.1bars	Deterioration of pump.	Replace pressure gauge and/or pump
Gap filter	- Controls cleanliness -Clean when the difference of pressure between the inlet and outlet of the filter is <0.3bars.	Biological clogging	Cleaning of filters and network
Sand filter	- Cleaning by back flushing once/year(let filtered water flow in a reverse direction via a stop cork - Change filter once every 2 years	Physical clogging	Chemical treatment with acid to neutralize the bicarbonate ions
Mesh filter	- Clean with a smooth nonmetallic brush - Rince the	Chemical clogging	Clean
Water reservoir	Check that the water pressure at the outlet should be 2.2 bars	Deposit particles	Empty and clean
Drippers	- Control the stoppling - Control the homogeneity of the rates by calculating the coefficient of uniformity (CU) CU›90: No reason to intervene 70‹CU‹90: Clean the network CU‹70: Search and treat the cause of clogging	Stoppling	Clean the network Treat the causes of clogging

VI. CONCLUSIONS

The drop-by-drop irrigation system presented throughout this work was applied for the culture of Vernonia amygdalina Delile. It is a contribution to the development of "clean agriculture", termed "new generation" and the expansion of all crops in the most arid zones. Its implementation was simple, cost effective and accessible to all.

The arrangement of the elements of the system takes into account the climate and the type of crop (water requirements as well as the density and flow rate of the drippers), the availability and quality of the water and the shape of the plot. It is easy to use and maintain. This system has a particular advantage; it can be used for any type of water including geothermal waters previously analyzed and treated according to conditions favorable to the crop to be cultured.

These advantages are remarkable and result in a significant energy and time savings. The empowerment of electric power with the use of photovoltaic solar panels, lead to the improvement of the production and the quality of the products thanks to the use of the fertilizers in the form of directly irrigable solution. Thus, fleshy large and numerous leaves were obtained at stems of V, amygdalina ready for marketing.

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