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Hydraulic Sizing of a Drip Irrigation System Coupled with the Technological Quality Test of Drippers

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Abstract **Original Research Article**

This article covers a methodology for hydraulic sizing of a drip irrigation system using irrigation water supply tanks. After a general description of the different components of the pressure irrigation network which is here drip, the theory of hydraulic sizing and the technological quality test of the drippers are very detailed in order to assess the performance of the latter. The adequate design of localized irrigation networks must necessarily be based on a good understanding of hydraulic principles so as to be able to correctly size the different components of the irrigation system. The trial on the technological quality test of drippers in a drip irrigation system consisted of testing these emitters using an experimental device. To this end, 3 reservoirs containing drinking water from the NDE were used to supply 3 drip irrigation networks. Measurements of flow rates and volumes made at the level of drippers, booms, boom holders and networks made it possible to verify the quality of the drippers used and the hydraulic performance of the pressure irrigation system. Data relating to these measures were collected and analyzed. It appears from this study that the corresponding pressures at different heights in the tanks are low and vary by 0.11bar and 0.15bar and that the pressure is a function of height. As for the flow rates and volumes of water measured at the drippers, valves, ramps, ramp holders and networks, they are hydraulically the same. In other words, they are statistically identical but in absolute value the flow rate of valve 1 is slightly higher than flow rates 2 and 3. Finally, regarding the technological quality test of the drippers, the flow rate variation coefficients obtained during this test are 0.052; 0.055; 0.056; 0.061 and 0.052 respectively at the water heights in the tank h1, h2, h3, h4 and h5. Then the different uniformity coefficients obtained at these heights are respectively 93.73; 94.26; 94.45; 95.02 and 94.77%. These values above 90% reveal excellent distribution of irrigation water to the plot. In conclusion, it is possible to carry out localized irrigation with few materials and therefore inexpensively. However, high establishment costs can constitute a constraint to the adoption of the technology. This is why it was recommended to make agricultural subsidies and credits available to producers to enable the large-scale dissemination of the drip irrigation system.

Keywords: Drip Irrigation, Hydraulic Sizing, Dripper Performance, Water Distribution Uniformity, Low-Cost Irrigation.

INTRODUCTION

In the Alliance of Sahel States (AES) zone in general and in Niger and Burkina especially, agriculture plays a key role in economic and social development (SOME, 2017). Indeed, in this fringe of Africa, rainfall ranges from 250 to more than 500 mm per year (FAO, 2005). Agricultural activities provide significant income to producers as well as populations.

Unfortunately this activity is increasingly confronted with a certain number of constraints including, among other archaic tools used, insufficient rainfall, rising temperatures, etc. Today, innovative and effective solutions are required. Thus, successive authorities have thought of placing emphasis on irrigated agriculture. From independence to the present day, the gravity irrigation system is the most used in Niger. Our producers water the majority by hand. This is hard work and results in low irrigation efficiency, thus limiting production and profitability (PASTERNAK *et al.*, 2006).

In addition to this water-consuming and wasting system, rainwater decreases from one year to another. Hence the need to use a water-saving irrigation system. Thus, for better water management, the drip irrigation system seems to respond positively to this criterion. In our semi-arid zones, according to IPALAC (2001), low-pressure drip irrigation is not only suitable for local improved cultivation techniques, but also adapts well to small areas of land. This technique is also recognized as labor-saving compared to surface irrigation and has several advantages (PASTERNAK *et al*., 2003). These advantages include: the plants receive the same amount of water and fertilizer, and the water tension in the soil is kept at a very low level throughout the day, an increase in yield and a improvement of product quality. Thus, a study on the drip irrigation system carried out in India by SIVAKUMAR (1994), demonstrated a water saving of 36-79% and an increase in yield of 2-98% compared to conventional drip irrigation systems. 'irrigation.

This study concerns the hydraulic sizing of a very low pressure irrigation system coupled with the Technological Quality Test of drippers. The research activities were carried out at the experimental sites of the Faculty of Agronomy of Niamey.

MATERIAL AND METHODS

Setting Up the Experimental Device

The experimental system is set up on the grounds of the Faculty of Agronomy of the Abdou Moumouni University of Niamey (Niger). This device comprises 3 cylindrical tanks of 0.6m in diameter and 1m in height, i.e. a volume of around 300l (282l). The water used is that supplied by the NDE.

The total surface area of the trial is 156 m2 (12m by 13m) made up of 3 irrigation blocks or networks of 14 m2 (7m by 2m) separated by 1m aisles. The dimensions of the valves and boom holders were checked with the optical level of the topographer. To respect the pressure which will give a flow rate of 1l/l, the valves were set at 0.32m compared to the level of the well-flattened natural ground (TN). Each tank serves, from the network supply valve, a ramp holder equipped with 4 ramps, each 7m long. The ramp, for its part, is equipped with 6 tasters spaced 1m apart.

The 1st and 6th drippers are respectively placed 0.5m and 6.5m from the boom holder, for a total of 24 drippers per network. The ramp holders and ramps are fixed to the ground with iron hooks 6 and 0.2m high, for a total of 100 hooks.

At each dripper, a 35cm deep hole is dug in which a 1.5l plastic bottle is housed. Above each bottle is placed a funnel to collect and estimate the volume of water delivered by each dripper. The experimental device consists of a total of 3 tanks serving 3 boom holders, 12 booms and 72 drippers.

Determination of water heights in the tank and corresponding pressures

Once the experimental device has been set up, the water levels in the 3 reservoirs must be measured after each 1 hour irrigation and this for 5 successive hours. A volume of 150l of NDE water is introduced into each of these 3 tanks where the initial water height h1 is 0.53m. A first irrigation of 1 hour was carried out bringing the water height to h2 then a 2nd, 3rd, 4th and 5th irrigations of the same duration were carried out giving respective heights h2, h3, h4 and h5 of water in the tank. These different water heights were measured after the 5 respective 1-hour irrigations, from which the corresponding water pressures are deduced. A device consisting of a pressure gauge made it possible to measure the different pressures.

Determination of supply valve flow rates (or boom-carrying flow rates)

The experimental device having been set up, the tank each containing 150l of tap water are placed at the natural ground level + 32cm, the valves placed 5 cm from the bottom of the tank (therefore tank side + 5cm). For flow measurements, these valves are disconnected from the transport pipes which connect them to the irrigation networks. For this purpose, a 5l container is placed below the valve 1, first opened completely, and the volumes of water delivered by the latter are measured for 10, 20 and 30s at the initial water height h1 in the tank (h1= 0.53m) each time returning the initial level of water in the tank after each measurement. After this first series of measurements, the water level in the tank is brought to the height h2 determined previously, the same measurements as at h1 are repeated and so on until the height h5. These flow rates obtained at different water heights in the reservoir are called flow rates of the supply valves of the irrigation networks or flow rates of the boom holders because they are supplied by the same respective flow rates through the transport pipes.

Determination of boom flow rates

After measuring the flow rates of different valves, the irrigation networks are connected to these supply valves.

The ramps are detached from the ramp holders, the water level in the tank being at the height h1= 0.53m, 5l containers are placed at the level of four (4) orifices of each ramp holder and the ramps are opened. Three (3) valves at the same time for 10, 20 and 30s. The respective volumes of water collected are measured at these three (3) time steps.

After measuring the flow rates for 10 seconds, the water level is brought back to the initial height to take the measurements for 20 seconds and we do the same for the flow measurements for 30 seconds. After the 3 flow measurements at height h1, the same measurements are carried out at the respective water heights in the tank h2, h3, h4 and h5. These flow rates delivered by the ramp holders more precisely at the level of the orifices and entering the ramps are called ramp flow rates.

Determination of dripper flow rates

Once the reference flow rates of the booms have been measured, the booms are connected to the boom holders and this time we launch a series of 5 successive irrigations at the respective water heights h1, h2, h3, h4 and h5 in the tank. At each ramp, the volumes of water delivered from 6 drippers are measured for a given height for 1 hour. These flow rates delivered by the different drippers are called dripper flow rates for a given water height.

Determination of network volumes

Each network is equipped with 24 drippers fixed on four ramps. The volumes of water delivered during irrigation with NDE water by all the drippers of a network at water heights in the reservoirs h1, h2, h3, h4 and h5 are evaluated by the arithmetic sum of these volumes.

The volumes of the networks evaluated are called network volumes for a given water height.

Determination of ramp volumes

During irrigations to evaluate the hydraulic functioning of the irrigation networks, the water delivered for 1 hour by the 6 drippers of a boom was evaluated by adding their respective volumes for a height and network considered. These evaluated ramp volumes are called ramp volumes for a given water height.

Technological quality or dripper flow variation test

Drippers were purchased whose flow coefficient of variation was not indicated by the manufacturer. Also, a flow variation test was carried out to assess the technological quality of the drippers. To carry out this type of test, it is recommended to use at least 50 drippers (Filali., 2010).

As far as we are concerned, 96 drippers with a nominal flow rate of 1l/h were used. This test is very important for any drip irrigation project or experiment because it allows you to use or not the drippers tested. The procedure consists of starting irrigation with the 96 drippers for 1 hour. At each dripper, a 1.5l bottle collects the water delivered by the dripper. The flow rate variation coefficient (Vt) is determined by the ratio of the Ecartype to the average flow rate of all the drippers tested.

$$Vt = \sigma / qm$$

With σ the standard deviation and qm the mean of the sample tested

After the first irrigation of 1 hour, we will determine the flow coefficient Vt1 and the corresponding height will be h1 and for the 2nd, 3rd, 4th and 5th irrigations, we will determine in this way Vt2, Vt3, Vt4 and Vt5 and the water heights in the tank will be h2, h3, h4 and h5 respectively. Vt1, Vt2, Vt3, Vt4 and Vt5 will be determined using the same formula.

The coefficients obtained will be compared to the dripper technological quality standards defined by Keller (1983).

Water distribution uniformity test at the level of irrigation networks (plots)

After having carried out the technological quality test of the dripper to be used, it is a question of checking how the water distribution is done on the plot (here network).

Is it uniform or not? To implement this distribution, the plot water distribution test will be carried out according to the formula used by Keller and Karmeli (1983) in determining the coefficient of uniformity of water distribution to the plot.

The test consists of testing the uniformity of distribution of irrigation water on a drip-irrigated plot.

The irrigation system is made up of 4 irrigation network units each made up of a plot with a spacing between booms of 1m and between drippers also of 1m. The drippers used are GR type diversion, delivering a nominal flow of 1l/h under a pressure of 0.1bar.

The uniformity test consists of measuring, in each plot unit, the flow rate at the level of 16 well-distributed drippers (Penadille., 1998; CEMAGREF., 2003). The flow measurements for calculating the uniformity coefficient are carried out on four ramps uniformly distributed along the ramp holder according to the device proposed by Penadille (1998) whose description is as follows: 4 ramps are selected at each network irrigation system and 4 drippers are maintained by booms, i.e. 16 drippers per network (Figure 2). For the ramps, this is the first ramp, the one located a third of the way up the ramp rack, the ramp that is two thirds of the way through the ramp rack and the last ramp.

Concerning the drippers selected, the first on the ramp, the second which is at 1/3 of the ramp, the third is at 2/3 of the ramp and the fourth dripper at the end of the ramp. Then, we measure the flow rate of each dripper. For our case, the test will be carried out with four networks each comprising 16 drippers (i.e. 64 measurements) and at 5 water heights in the irrigation water supply network h1, h2, h3, h4 and h5. The study of the uniformity of water distribution at the level of the irrigated plot is based on the uniformity coefficient (CU) of Keller and Karmeli., (1974). The higher the latter, the better and therefore uniform the water distribution. For a given water height and for each network made up of 16 drippers, the distribution uniformity coefficient CU is calculated using the formula below including the average flow rate qm of 16 drippers, the average of the four highest flow rates weak and the expression of Keller and Karmeli which is:

$$CU = 100 * q_{m4} / q_{m16}$$

With
- qm16 = average of the 16 values obtained;
- qm4 = average of the four lowest flow values.

Figure 1: Measuring device adopted for determining the Uniformity coefficient

This device makes it possible to measure 16 flow rates for all the drippers in a network and to calculate their average. We will take the 4 drippers (i.e. 1/4) which have the lowest flow rates in the network. We thus obtain the data necessary for the calculations of the uniformity coefficients according to the formula mentioned above.

The materials used to carry out this test are:
- stopwatch (measuring time set at 1 hour);
- 1.5l plastic bottle;
- 1l graduated cylinder;
- and Data collection sheets.

The interpretation of the results of the calculations of the different coefficients of the uniformity of water distribution as a function of water height in the tank (pressure) will be done based on the reference values of CU making it possible to assess the quality of uniformity of watering. These values are summarized in Table 1.

Table 1: Value of the distribution coefficient and assessment of uniformity in the plot (CEMAGREF., 1992) reported by COMPAORE., (2003)

Uniformity Coefficient Value	Appreciation of Uniformity
CU > 90	Excellent
80 < CU < 90	Satisfactory
70 < CU < 80	Poor
CU < 70	Bad (Clogged network)

RESULTS AND DISCUSSION

The results which follow relate initially to the flow rates of the valves, booms and drippers then secondly to the reference volumes of these same elements. In addition, the technological quality of the drippers and the uniformity of water distribution to the plot will be determined.

RESULTS

Water heights in the tank and corresponding pressures

Table 2 respectively illustrates the water heights in the reservoir for the 5 successive 1-hour irrigations and the corresponding pressures.

Table 2: Pressures as a function of water height in the tank

Tank Water Height	Corresponding water pressure (bar)			
	Reservoir 1	Reservoir 2	Reservoir 3	Ecartype
0,53m	0,15	0,149	0,1485	0,0007
0,43m	0,14	0,141	0,1394	0,0008
0,336m	0,13	0,129	0,1293	0,0005
0,24m	0,12	0,119	0,1183	0,0008
0,155m	0,11	0,11	0,11	0

Each height of water in the tank corresponds to a pressure which will control the flow of the fluid, in this case water. Determining the water levels at each irrigation will influence the water flow at the valve, boom holder, booms and drippers. It is therefore important to determine them at each irrigation with tap water delivered to the Faculty of Agronomy used as very suitable for drip irrigation. For each water height hi delivering a flow rate qi corresponds to a pressure pi. Table 2 gives the water levels in the 3 reservoirs after each irrigation. From this table, we note that whatever the reservoir considered, the pressures decrease by a height. On the other hand, the pressure values at a height are practically identical with a very low Deviation and decrease regularly like those at heights. The water heights obtained will be used in all the different tests.

Flow Rates Obtained

Flow rates of valves or boom holders

Valves V1, V2 and V3 of tanks R1, R2 and R3 were opened to respective heights of 0.155; 0.336m and 0.53m. Table 4 gives the average inter-valve flow rates at a given height.

Table 4: Average inter-valve flow rates at a given height

Modality	Average estimated	Groups								
H0,155*V1	23,928		A							
H0,155*V3	24,018		A							
H0,155*V2	24,002		A							
H0,336*V1	27,938				B					
H0,336*V3	28,112				B					
H0,336*V2	28,112				B		C			
H0,53*V1	31,756						C			
H0,53*V3	31,900						C			
H0,53*V2	32,073									

From this table, it appears that the valves have statistically the same flow rates at each height considered.

Table 5 displays the average valve flow rates at the different heights.

Table 5: Boom holder flow rates (valves) as a function of water height in the tank (l/h)

Tank Water Height	Ramp holder 1	Ramp holder 2	Ramp holder 3	Ecartype
0,53m	31,7988	32,2908	31,7136	0,31
0,43m	29,9772	30,0144	29,7312	0,15
0,336m	28,0644	27,6432	27,612	0,25
0,24m	23,814	24,1872	23,7984	0,22
0,155m	21,3396	21,6456	21,864	0,26

Ramp Flow Rates or Incoming Ramp Flow Rates

The ramps transport the water which will supply the drippers. The incoming flow rates of the booms were measured at the orifices connecting the boom holders to the booms.

To check the previous results, the averages per height in Table 6, all ramps combined, were compared on the one hand, and on the other hand, the averages of four (4) ramps, all heights combined. Table 6 compares the averages by height for all ramps combined.

Table 6: Average flow rate of the booms as a function of height

Modality	Average estimated	Groups				
H0,155	5,391	A				
H0,24	5,980		B			
H0,336	6,945			C		
H0,43	7,477				D	
H0,53	7,963					E

The table above confirms the difference in flow rates between the heights.

Table 7, for its part, compares the averages of the ramps for all heights combined.

Table 7: Average water flow rates delivered from booms at all heights combined

Contraste	Pr > Diff	Significatif
H0,155 vs H0,53	<0,0001	Oui
H0,155 vs H0,43	<0,0001	Oui
H0,155 vsH0,336	<0,0001	Oui
H0,155 vs H0,24	<0,0001	Oui
H0,24 vs H0,53	<0,0001	Oui
H0,24 vs H0,43	<0,0001	Oui
H0,24 vs H0,336	<0,0001	Oui
H0,336 vs H0,53	<0,0001	Oui
H0,336 vs H0,43	<0,0001	Oui
H0,43 vs H0,53	<0,0001	Oui

Table 8 gives the analysis of variance of the water flow rates delivered between the booms (1, 2, 3, 4 and 5). From this table, it is found that the p-values are all greater than 0.05. This indicates that there is not a significant difference in flow rates between the different ramps.

These p values are 0.335, 0.614, 0.844, 0.442, 0.758 and 0.645 respectively for ramps 1 and 3, ramps 3 and 2, ramps 3 and 4, ramps 1 and 4, ramps 2 and 4 and ramps 1 and 2.

Table 8: Average water flow rates delivered between the booms

Contraste	Pr > Diff	Significatif
R3 vs R1	0,335	Non
R3 vs R2	0,614	Non
R3 vs R4	0,844	Non
R4 vs R1	0,442	Non
R4 vs R2	0,758	Non
R2 vs R1	0,645	Non

Given that the flow rates of the ramps are statistically homogeneous for a given height of water in the reservoir, table 9 is deduced to illustrate the average flow rates of the ramps or reference ramp flow rates.

Table 9: Average incoming ramp flow rates (l/h) as a function of water height

Water Height (m)	Network	Ramp				Ecartype
		Ramp 1	Ramp 2	Ramp 3	Ramp 4	
0,53	1	7,9932	7,9392	7,9188	7,9476	0,03
	2	8,1396	8,0904	7,9932	8,0676	0,06
	3	7,9092	7,8948	7,9776	7,932	0,03
0,43	1	7,476	7,5	7,4892	7,512	0,01
	2	7,494	7,5084	7,5252	7,4868	0,02
	3	7,4148	7,44	7,4448	7,4316	0,01
0,336	1	7,0248	7,0068	6,99	7,0428	0,02
	2	6,9372	6,9228	6,8832	6,9	0,02
	3	6,9324	6,9048	6,8952	6,8796	0,02
0,24	1	5,9484	5,9796	5,922	5,964	0,02
	2	6,0408	6,0144	6,0768	6,0552	0,03
	3	5,958	5,9388	5,982	5,9196	0,03
0,155	1	5,3304	5,3412	5,3556	5,3124	0,02
	2	5,4108	5,4108	5,3916	5,4324	0,02
	3	5,4564	5,4732	5,4948	5,4396	0,02

In this table and for a given water height in the tank, the ramps have identical flow rates. From the water height in the tank h1 to the height h5, the flow rate decreases from one height to another due to the drop in pressure.

For a given water height, the flow rates recorded at ramps 1, 2,3 and 4 are the same at each water height and are around 8 l/h, 7.5 l/h, 6.9 l /h, 6 l/h and 5.4 l/h respectively at heights of 0.53m and 0.43m in the 3 irrigation networks. The flow rates of each of 4 ramps of the same network were calculated by the following formula:

$$Q_{rampe} = Q_{vanne} / Nr$$

With:
Qrampe (L/h): unit flow rate of the booms
QValve (L/h): average tank emptying flow
Nr: total number of ramps powered (Nr=4)

Dripper Flow Rates

Drippers always deliver water to the plant. For all 3 irrigation networks, their flow rates were measured during three irrigations of 1 hour each at water levels h1, h2, h3, h4 and h5. At each dripper, the average of three (3) measured flow rates was taken and is considered average dripper flow or dripper flow. The flow rates of the drippers will be compared to the flow rates delivered by the respective drippers obtained during irrigation.

Network Reference Volumes

Remember that each network has 24 drippers, the reference volume of a network is determined by taking the arithmetic sum of the volumes of water delivered by the 24 drippers. Table 10 records the volumes of 3 networks during irrigation at different water heights in the reservoir.

Table 10 gives the average volumes of irrigation networks (l) obtained during irrigation at different water heights.

Table 10: Average volumes (l/h) of irrigation networks obtained during irrigation at different water heights

Tank water height	Networks				
	Network 1	Network 2	Network 3	Average	Ecartype
0,53m	21,92	21,95	21,93	21,93	0,012
0,43m	20,32	20,34	20,34	20,33	0,009
0,336m	19,3	19,33	19,33	19,33	0,015
0,24m	18,91	18,95	18,97	18,94	0,025
0,155m	17,36	17,38	17,36	17,37	0,009

Volumes of Water Delivered by the Booms

The delivered boom volume is the arithmetic sum of the volumes of water delivered by the 6 drippers of each boom.

Tables 11, 12 and 13 illustrate the water volumes of the ramps of networks 1; 2 and 3 irrigation 1(liters) at different heights.

Table 11: Average water volumes of the booms of the irrigation network 1 (liters) at different heights

Tank water height	Ramps				
	Ramp 1	Ramp 2	Ramp 3	Ramp 4	Ecartype
0,53m	5,47	5,42	5,45	5,57	0,06
0,43m	5,05	5,06	5,08	5,3	0,12
0,336m	4,8	4,8	4,77	4,9	0,06
0,24m	4,66	4,74	4,84	4,68	0,08
0,155m	4,30	4,32	4,31	4,42	0,05

As the drippers have a flow rate of 1l/h, we had to have 6l at each ramp. But this was not the case due to singular and linear pressure losses.

Table 12: Water volumes of the irrigation network booms 2 (liters) at different heights

Tank water height	Ramps				
	Ramp 1	Ramp 2	Ramp 3	Ramp 4	Ecartype
0,53m	5,62	5,47	5,42	5,44	0,09
0,43m	5,27	5,07	5,03	4,97	0,13
0,336m	4,94	4,67	4,83	4,87	0,11
0,24m	4,73	4,72	4,69	4,81	0,05
0,155m	4,36	4,30	4,25	4,47	0,09

Table 13: Water volumes of the irrigation network booms 3 (litres) at different heights

Tank water height	Ramps				
	Ramp 1	Ramp 2	Ramp 3	Ramp 4	Ecartype
0,53m	5,43	5,52	5,52	5,42	0,05
0,43m	5,16	5,12	4,97	5,08	0,08
0,336m	4,79	4,73	4,86	4,98	0,11
0,24m	4,81	4,66	4,69	4,81	0,08
0,155m	4,29	4,38	4,28	4,37	0,05

Each ramp is equipped with 6 drippers. It is obtained by the sum of volumes of water delivered by the 6 drippers of a boom at a given height. This involves verifying on the scale of 3 networks that the ramps provide the same flow rates at a given height. The volumes delivered by the 6 drippers of a boom were evaluated for 1 hour of irrigation at the respective heights h1, h2, h3, h4 and h5. Tables 11; 12 and 13 record the volumes of the ramps at the level of the respective networks 1; 2 and 3 depending on water height and time. We see that the ramps give almost the same volume of water at a given water height and time step. Tables 14 and 15 give the average, minimum and maximum flow rates of drippers per network.

Table 14: Average, minimum and maximum flow rates of drippers per network for water heights in reservoirs h1=0.53m, h2=0.43m and h3=0.336m

Flow	h1=0,53m			h2=0,43m			h3=0,336m		
	Network1	Network 2	Network 3	Network1	Network 2	Network 3	Network1	Network 2	Network 3
qm	845,25	863,75	881	842,12	860,19	891,37	798,87	818,25	846,06
qmin	837	847	857	783	800	810	737	753	767
qmax	1000	993	993	927	927	935	877	853	913

Table 15: Average, minimum and maximum flow rates of drippers per network for water heights in reservoirs h4=0.24m and h5=0.155m

Flow	h4=0,24m			Hh5=0,155m		
	Network1	Network 2	Network 3	Network 1	Network 2	Network 3
qm	754,75	785,06	803	704,06	725,2	754,5
qmin	710	723	737	677	673	693
qmax	810	823	867	760	755	830

For all the networks, we see that at the level of different valves, the average, minimum and maximum flow rates have experienced variations.

In the drip irrigation system, such relatively small variations indicate a homogeneous distribution of water to the plot.

Technological Quality of Drippers

The technological quality of the drippers goes hand in hand with the value of their flow coefficient of variation (Vt). Remember that the coefficient of variation is determined by measuring, in each plot unit, the flow rates of 16 well-operated drippers on four ramps uniformly distributed along the ramp holder according to the device proposed by Penadille (1998). Thus, CU is calculated using the average flow rate qm of 16 drippers and the average of four lowest flow rates. Table 42 gives the flow rate variation coefficients as a function of water heights in the reservoir.

The dripper is one of the driving parts in a drip irrigation system. Its behavior is very decisive on the expected level of production. The quality of the dripper chosen was verified through the test of variation in dripper flow at different water heights in the tank. According to tables 14 and 15, whatever the water height considered, the coefficient obtained meets the criterion of good technological quality of the drippers used. The coefficients of variation of flow rates vary from 0.061; 0.052 whatever the height considered.

Variation of Dripper Flow Rates by Network

Table 16: Flow rate variation coefficients (Vt) as a function of water heights in the reservoir

Water Height	Average dripper flow (ml)	Ecartype	Vt obtained	Reference coefficients of variation (Keller,1983)
0,53m	931,28	48,65	0,052	**0,04 < Vt < 0,07**
0,43m	876,88	48,26	0,055	
(0,336m)	846,12	47,65	0,056	
(0,24m)	801,51	49,24	0,061	
(0,155m)	742,29	38,9	0,052	

Uniformity of Water Distribution at the Network Level (Plots)

Table 17 illustrates the coefficients of uniformity of water distribution on the plot (CU) as a function of water levels. The technological quality test revealed that the drippers used are of good quality but this must be supplemented by checking the distribution of irrigation water to the plot. This table gives the different CUs obtained depending on the heights and their assessment in relation to the water distribution.

Regardless of the water height considered, the uniformity coefficients of water distribution to the plot obtained are > 90, which indicates excellent water distribution at the plot level. These distribution uniformity coefficients vary from 93.73 to 95.02.

Table 17: Coefficients of Uniformity of water distribution on the plot according to water heights

Water Height	Network 1	Network 2	Network 3	Average	Appreciation Uniformity Coefficient
0,53m	92,85	94,32	94,02	93,73	Excellent
0,43m	94,42	94,53	93,83	94,26	Excellent
0,336m	94,62	95,35	93,38	94,45	Excellent
0,24m	96,29	93,75	95,02	95,02	Excellent
0,155m	96,87	93,14	94,3	94,77	Excellent

From this table and referring to the CEMAGREF classification (1992), all the CU coefficients are greater than 90%, this indicates a good condition of the networks.

In summary, the tests with tap water delivered by the NDE showed that the networks function properly.

DISCUSSION

This study shows that the different networks of the irrigation system set up operate hydraulically as a single network. Thus, the supply valves of these networks are placed at the TN+ 32cm rating so they are at the same level. This is verifiable at 6 levels for an irrigation considered: 1) height of water in the tank, 2) pressure, 3) flow rates recorded by the valves 4) flow rates delivered by booms, 5) volumes delivered by the valves and 6) the volumes delivered by the ramps. Regarding the height of water in the tank, with a volume of water of 150l in each of 3 tanks, 5 successive irrigations of 1 hour were carried out. In addition, depending on the water levels in the reservoir, each irrigation was carried out. The pressures corresponding to these heights are low and vary from 0.11bar to 0.15bar. We see that the pressure is a function of the height and the difference in pressure between the points is due to the difference in heights between them (Morarech., 2017).

Considering the boom holders, these are the volumes of different valves that feed them, they are hydraulically the same. It appears that valves 1, 2 and 3 deliver flow rates that are statistically identical but in absolute value the flow rate of valve 1 is slightly higher than flow rates 2 and 3.

These results confirm the results obtained by YE Dofindoubê (2010) in Burkina Faso where the volumes obtained at valves 1 to 8 are slightly different.

These differences could possibly come from the technological manufacturing quality. This is in line with the principle according to which, in industry, it is very difficult or even impossible to manufacture two perfectly identical products; this difference often leads to slight variations (Filali., 2010). Regarding the flow rates of the booms, the results showed that the flow rates delivered by the 4 booms are homogeneous. These results match those obtained by El Amri *et al*., (2012) who, by conducting irrigation with GR type drippers at a water height in the reservoir of more than 1m under a pressure of 1bar with a nominal flow rate of 4l/h, obtained identical flow rates. On the other hand, these results are contrary to those of Asma *et al*., (2013) who found different flow rates at the ramps. This difference would be due to the nature of the drippers used but also to the difference in internal diameters. In fact, they used ramps with an internal diameter of 4.8 mm and 1 mm for our case. For the flow rates delivered by the drippers, they are not identical for the most part regardless of the network and the height considered.

Considering the height h1 of networks 1, 2 and 3, 66.7% of the drippers deliver flow rates approximately equal to the nominal flow rate (networks 1 and 2), 75% of the drippers give flow rates close to the nominal flow rate compared to 25% different (network 3). On the other hand, El Amri *et al*., (2012) only obtained 10% of drippers which gave a flow rate close to the nominal flow rate. This difference would come from the length of the ramps (50 m) compared to 7 m in our case which would in turn generate greater variations in dripper flow rates. Due to the reduction in pressure (Batiebo., 2006), for a given ramp, hydraulically, the volume of water delivered by the drippers decreases when we tend towards the lower limit of the latter due to the reduction in pressure pressure.

As for the networks, the volumes of water delivered during irrigation with tap water are statistically identical at each height considered.

Thus, they decrease in a decreasing manner from water heights h1 to h5 with respective efficiencies of 91.42 to 72.36%. These results confirm the results obtained by Zellal *et al*., (2007) on the efficiency of the drip irrigation system.

The flow rate variation coefficients obtained during the technological test of the drippers are 0.052; 0.055; 0.056; 0.061 and 0.052 respectively at the water heights in the tank h1, h2, h3, h4 and h5. Keller (1983) made a classification of drippers based on flow rate variation coefficients.

We then note that these coefficients are between 0.04 and 0.07, which indicates the good quality of the drippers. Whatever the water height considered, the results show that the drippers tested are of good technological quality. Which means that the technological variation coefficient Vt is independent of pressure (Asma *et al*., 2013; Mermoud., 2004).

The different uniformity coefficients at the respective heights of h1, h2, h3, h4 and h5 are 93.73; 94.26; 94.45; 95.02 and 94.77%. These values above 90% reveal excellent water distribution to the plot (CEMAGREF., 1992). On the other hand, Wli P *et al*., (1974) propose a CU between 0.95 and 0.98 in drip system equipment to speak of an acceptable CU as the absolute lower tolerable limit.

CONCLUSION

The uniform distribution of water on the plot is one of the fundamental objectives sought in the drip irrigation system.

The study carried out focused on the experimental evaluation of the hydraulic functioning of different components of 3 networks, also through the test of the technological quality of the drippers then the test on the uniformity of water distribution at the level networks.

The comparison of the different flow rates and volumes at the level of the valves, boom holders, ramps and even drippers show that at the same pressure, the flow rates and volumes obtained with the water are statistically identical depending on the tanks and heights.

The uniformity of application was studied on an experimental site composed of 3 networks, irrigated with water drip. The study was based on the uniformity coefficient defined by Keller and Karmeli determined by following the procedure based on flow measurements of 16 drippers uniformly distributed on each unit. In addition, the differences between the nominal flow rate and the measured flow rates of the drippers were determined. The results revealed that all of the measurements correspond to a uniformity coefficient greater than 90% at the level of 3 networks. Added to this are the small differences recorded between the measured flow rates and the nominal flow rates of the drippers and booms to confirm the good uniformity of irrigation on the plot and the absence of any malfunction of the various networks. This shows that the drippers used work well under the experimental conditions.

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