Control of « Horticulture Easy Drip Kit de 100 m² » hydraulic characteristics for micro irrigation in Mali

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Abstract

Precarity of water resources in Mali, justify the high need to develop irrigated agriculture with micro irrigation system. "Horticulture Easy Drip Kit 100 m²" is a simple equipment for this kind of irrigation and have been imported from India for small farmers interested in vegetable production. The present study aimed to evaluate its hydraulic performance and adaptability. It is based on direct measurements of drippers' debit (by volumetric method), evaluation of debit variation coefficient (VC) and calculation of Reynolds number (Re), Keller and Karmeli uniformity coefficient (UC), UC according old network method. The study showed that the tool has a laminar flow. Strong correlation between flow and pressure was noted, indicating normal hydraulic functioning. Drippers debit are not homogeneous (VC > 10%), as well as water distribution to irrigation station (UC < 90%), indicating a malfunction of the network. The Functioning Optimal Charge (FOC) are 0.6m and 1.5m. The tank manual filling at 1.5m is very difficult or impossible and not recommended for small farmers. The simplicity of tool is favorable for its extension in vegetable growing areas of Mali. However, research is needed to improve its hydraulic performance.

Keywords: Drip irrigation, Functioning optimal charge, Flow regime, Mali

1.Introduction

Irregularities in rainfall and climate crises recurring in the Sahelian zone of West Africa, thus justifying the shared concern of developing irrigated agriculture [1] (FAO, 2002). In this difficult climate context, where small farmers are the majority (80% of active population), the design of irrigation should be done with attention. The drip irrigation identified as a relevant technique in many parts of the world [2,1,3] (Bralts and Edwards, 1986; FAO, 2002; Elattir, 2002) seems to be proposable in this environment. So Winrock International imported from India a simple equipment ("Horticulture Easy Drip Kit 100 m²") for small farmers involving in vegetable production in Mali. It is a comprehensive network of drip irrigation, using the technique of low pressure [4,5] (Coulibaly et al, 2009; Coulibaly, 2011). In this kind of irrigation network, the main objective to be achieved in the calculation as in standardizing operating at maximum possible drippers debite, to avoid the great disparity between water volume supplied to crops [1] (FAO, 2002). Several parameters may influence variations in uniformity [6] (Zella et al, 2003): they include structural and dimensional parameters (dippers and conducts characteristics, space between between ramps, network geometric structure), functional parameters (network head pressure) and environmental ones (slope, temperature of water and air, water quality). Several studies have focused on the design of simulation scenarios of micro-irrigation systems in order to choose the best combination of parameters and maximize agricultural production [7, 8, 9] (Christiansen, 1942; Wu and Gitlin 1974; Zella and Kettab, 2001). Drippers are normalized by their pressure, usually supplied by the manufacturer (Law Flow - pressure) and practice debits from 2 to 50 l / h [10] (Vermeiren and Jobbing, 1983). Considering the weakness of drippers debits, a small variation of pressure (20%) can generate 10% debit gap, considered as an upper limit. Concerning Uniformity Coefficient (CU), it must be superior to 95%. A tolerance limit is imposed on the dripper itself through its technological Variation Coefficient $VC_{f,}$ that does not exceed the value of 10% [11] (Solomon and Dedrick, 1995). Such information is lacking in the equipment "Horticulture Easy Drip Kit 100 m²" proposed to small farmers in Mali. Assessment of hydraulic performance of this equipment is a necessity for users and that justified the present study [5] (Coulibaly, 2011). It aimed to evaluate drippers' debit variation coefficient (VC) and calculation of Reynolds number (Re), Uniformity coefficient (UC) and Functioning Optimal Charge (FOC) of the network.

2. Material and methods

2.1 Equipment

"Horticulture Easy Drip Kit 100 m²" IDA design, imported from India is the subject of the present study. In this micro irrigation equipment, water supply is made by a metal drum as tank, which capacity is 200 liters ; usually this tank is worn at 0.4 to 1.5m height, above the ground, with 0.6m as the value recommended by NGO diffuser of the equipment among gardeners. The kit is composed, from upstream to downstream, by a filter, a door ramp (about 14m long and 16.4mm in diameter), 5 ramps (10m long and 12.8mm in diameter each) and drippers in capillary black polyethylene (0.6m long and 1mm in diameter). Each ramp has 10m long and serve 30 drippers grouped into 15 pairs. The entire unit has 150 drippers and works with debit along and zero at the extremity. The experimental plan is shown in Fig.1 and 2.

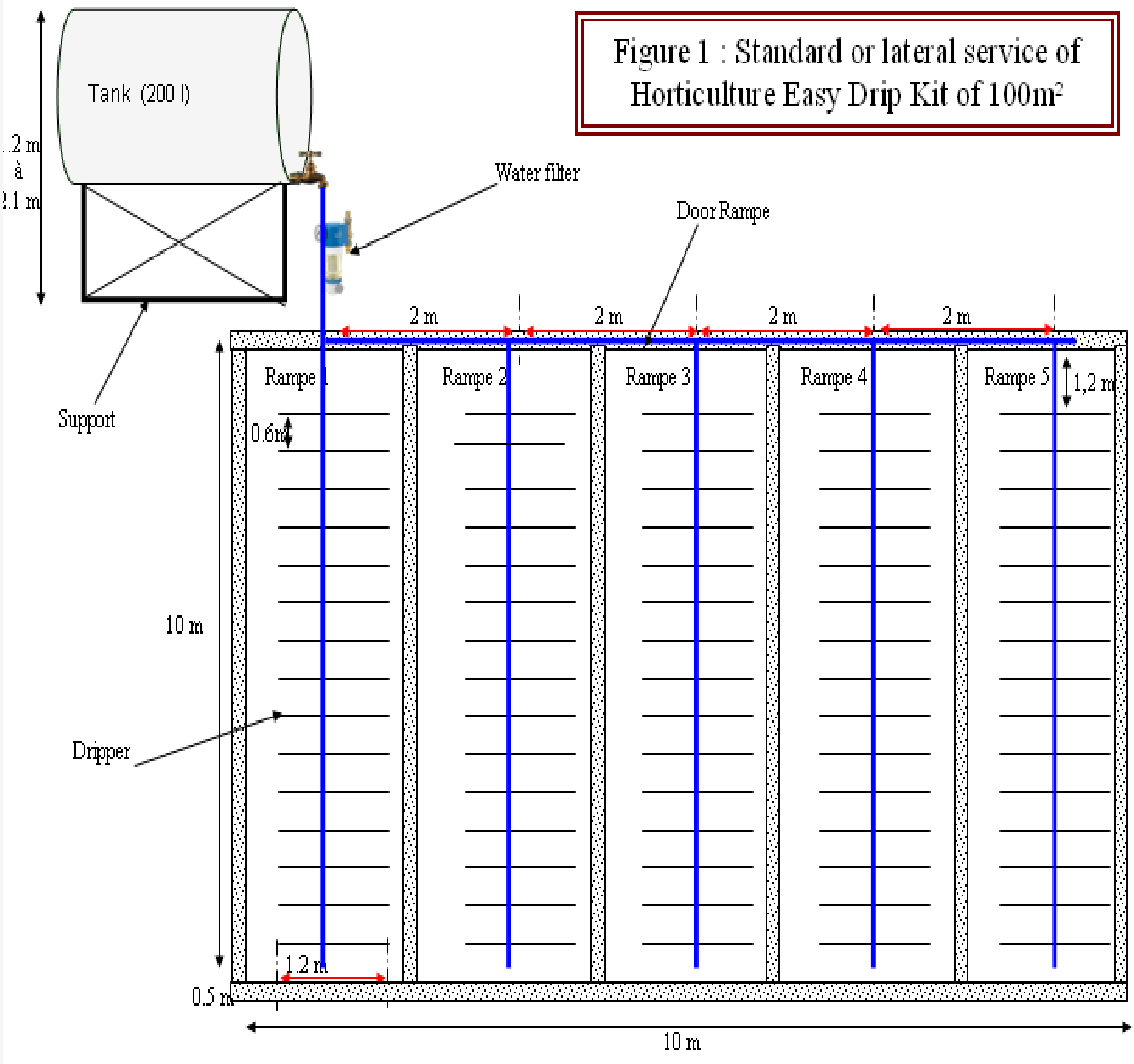

Figure 1 : Standard or lateral service of Horticulture Easy Drip Kit of 100m²

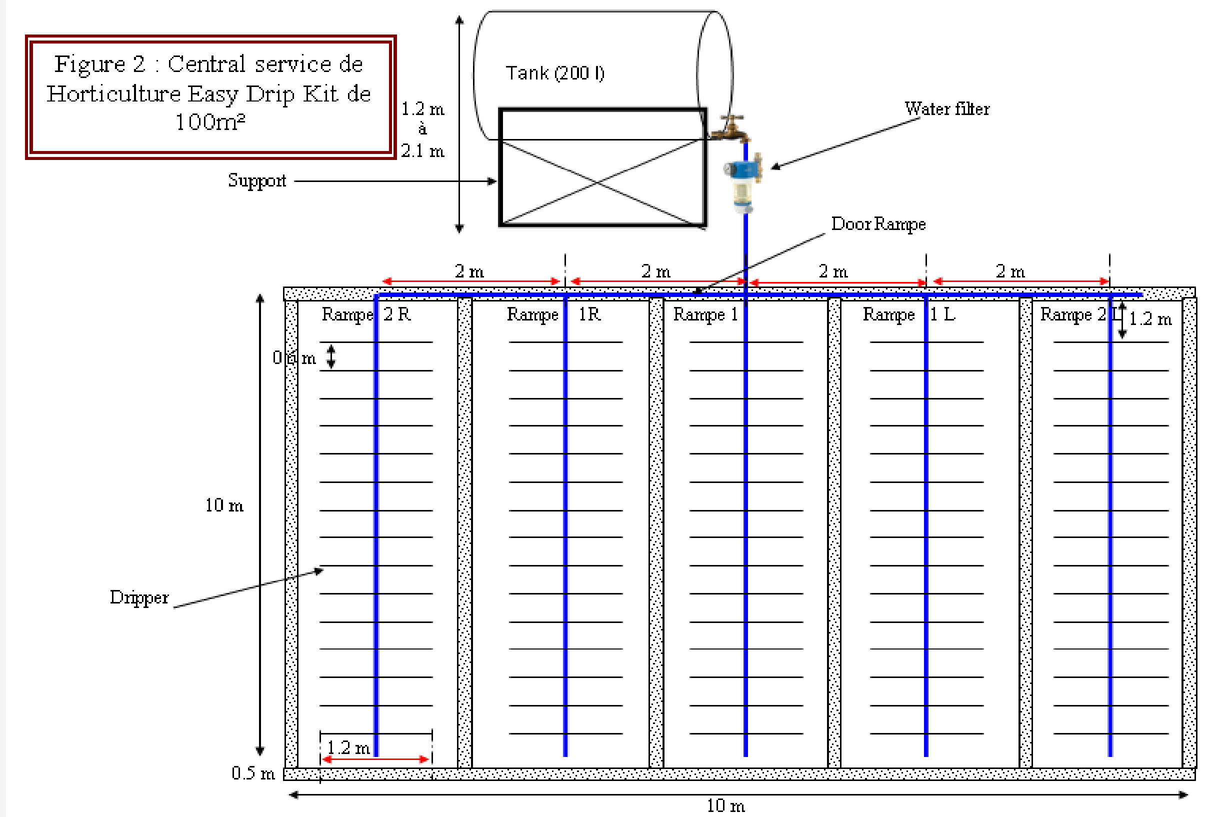

Figure 2 : Central service de Horticulture Easy Drip Kit de 100m²

2.2 Experimental apparatus and debit measurements

In order to measure the dripper's debit, two functioning diagrams of the network have been installed: the lateral service (standard), keeping the pressure system by its lateral bordered and the central one, keeping the pressure system from the center. Three different pressures were tested: H1, H2 and H3, corresponding respectively to 0.6m, 1m and 1.5m. These values are the pressure applied by the farmers in vegetable production. Each dripper debit was measured 18 times, that equals to 2,700 measurements for 150 drippers of the experimental dispositive. It should be noted that these measures were divided between lateral and central services.

2.3 Hydraulic parameters calculation

This calculation concern: Reynolds number (Re) and Uniformity Coefficient (UC). It permit to know the Functioning Optimal Charge Fixing (COF).

The flow regime of the network defined by the Reynolds number Re (a dimensionless number) was calculated in capillary tubes:

$$R_e = \frac{Vd}{\nu} \qquad (1)$$

Re = Reynolds number, V = flow velocity in the conduct (m/s) d = diameter of conduct (m); ν = kinematic viscosity of water (m^2/s).

If Re < 2000, is facing a laminar flow; if Re> 2000 it is a turbulent flow.

The Uniformity coefficient (UC) of water distribution in irrigation station was calculated using two methods: Keller and Karmeli method and control method of closure and homogeneity of drippers for old network.

According to Keller and Karmeli (1974):

$$UC = 100\frac{q_{min}}{\bar{q}} M_r f(e) \qquad (2)$$

q_{min}: minimum flow of drippers, determined according to the law flow- pressure as a function of the minimum pression; $\bar{q}$ = average flow of drippers of the network; Mr : quality coefficient of the fabrication equipment; f (e) = correction factor taking into account the number of dripper per plant.

According to the control method of closure and homogeneity of drippers for old network

:

$$UC = \frac{q_{min}}{\bar{q}} 100 \qquad (3)$$

q_{min}: minimum measured flow of drippers; $\bar{q}$ = average measured flow of drippers

It should be noted that this last method is applied to networks already in operation and is made mandatory at the beginning of every cropping season. It can be performed in cases where drippers are old and where the network is poorly maintained, and each time we find heterogeneity in irrigation. It consists in measuring debits (by the volumetric method) of 4 drippers by ramp, among 5 ramps. Ramps chosen here are the 2 first and the 2 last of the network. On a ramp, the first and the last

drippers are chosen, as those at 1/3 and 2/3 of the length of the ramp. Debit measured are classified in ascending order. We calculate the average q_{min} of the four lowest values of debit and $\bar{q}$ of measured debit of the network.
With these calculations of UC, it must be possible to choose the Functioning Optimal Charge (FOC). The objective in this selection is to identify the network system that has the best layout of main conducts (ramp and ramp door) and the best installation height of the tank. The better FOC is the one were debit and UC are maximum.

2.4. Statistical treatment of data

The data collected were subjected to statistical analysis using Excel. The means values debits of drippers was calculated, as well as their variance and the correlation between debit and pressure driving to the drippers nominal debit.

3. Result and discussion

3.1 Nominal flow (DN) of drippers

Nominal debit of drippers at pressures H1 (0.6 m), H2 (1m) and H3 (1.5m) meets the formula:

$$q = K_d H^x + a \qquad (4)$$

q is the nominal debit ; Kd is the specific coefficient of each unit dripper; x is the exponent related to the flow regime equation and a is a constant.
x=1; a<0
This formula differs from the one accepted as a dripper nominal debit, where the constant a is zero. It remains the equation of a straight line.
The value of x obtained here (x = 1) indicate a laminar flow regime.
Statistical analysis of the measured debits (Table 1) shows a homogeneous average debit of drippers (VC = 20% in central service and VC = 21% in lateral service) in the case of H3 and a disparity of the debit in the case of H1 and H2 whatever service (central or lateral).
Note that the laminar flow regime which characterized the network here is particular in micro irrigation system, where turbulent flow regimes are observed [7, 12, 10] (Christtiansen, 1942; M. Carlier; 1980; Vermeiren and Jobbing, 1983). As noted in Table 1, there is a strong correlation between debit and pressure in both lateral and central services. That means a normal hydraulic functioning.

Table 1: Drippers nominal debit of "Horticulture Easy Drip Kit 100 m²"

Network			Nominal debit		
Pression H (m)	Service	$\bar{q}$ (lh^{-1})	$q_{nominal}$ (lh^{-1})	r	VC %
0.6	Latéral	0.82	q = 9.5H – 7.23	0.70	32
	Central	0.87	q = 8.83H – 7.58	0.65	34
1	Latéral	0.90	q = 13.87H - 16.27	0.76	41
	Central	1.07	q = 12.12H - 15.29	0.73	42
1.5	Latéral	1.15	q = 10.88H – 17.81	0.71	20
	Central	1.37	q = 15.70H – 26.44	0.78	21

3.2 Flow Regime in the network

Re values vary from 145 to 242 (Table 2). Inertial forces are then clearly dominated by the forces of friction and it is assumed that the flow regime is laminar in the network.

Table 2: Flow Regime in the network "Horticulture Easy Drip Kit 100 m²"

Pression H (m)	Service		q_{moy} (l/h)	Diameter (mm)	R_e	Flow regime
0.6	Latéral	Dripper	0.4	1	145	< 2000 laminar
	Central		0.4	1	154	
1	Latéral		0.5	1	159	
	Central		0.5	1	189	
1.5	Latéral		0.6	1	203	
	Central		0.7	1	242	

3.3 Uniformity coefficient (UC) of water distribution

As shown in Table 3, the calculated values of UC, according to Keller et Karmeli, vary from 7 to 20% regardless of the pressure in the network. These values are well below the threshold floored (70%). However, there is a difference according the pressures tested: H1 (0.6m) and H2 (1m) are much better than H3 (1.5m). Unlike the other two cases, with pressure H3, the central service seems to work better than the lateral one (respectively 10% and 7% as values of UC).

According to the control method of closure and homogeneity of drippers for old network, only the lateral service of H3 has an acceptable homogeneity (UC = 71%> 70%). In all other cases, the values are below the threshold UC floored (Table 3). These results are not conform to those of Keita and Leeuwen (2002) [14], who found a UC > 90% (from the formula of Keller et Karmeli) working on a network of micro irrigation powered by a treadle pump to irrigate 2000 m^2.

Despite malfunction of "Horticulture Easy Drip Kit 100 m²," evidenced by the values of UC, we may retain FOC = 0.6m according Keller et Karmeli method and FOC = 1.5m according the old network one.

Table 3: Uniformity coefficient (UC) of water distribution of "Horticulture Easy Drip Kit 100 m²"

Network				CU	
				Keller et Karmeli method	Old network method
Pression H (m)	Service	$\bar{q}$ (lh^{-1})	q_{min} (lh^{-1})	(%)	(%)
0,6	Latéral	0,82	0,30	20	37
	Central	0,87	0,43	18	50
1	Latéral	0,90	0,39	19	44
	Central	1,07	0,65	14	61
1,5	Latéral	1,15	0,81	7	71
	Central	1,37	0,92	10	67

5. Conclusion

Studies show that the network has a laminar flow regime with a strong correlation between debit and pressure, indicating normal hydraulic functioning. However the measured debits are not homogeneous, as water distribution according to the methods used (Keller et Karmeli, old network method). So "Horticulture Easy drip Kit 100 m²" is not yet adapted to the requirement of material drip to drip. Against, its simplicity makes it a better material for small Sahelian farmers, hence the need for further research to improve the uniformity of irrigation. In a temporary situation, an installation height of 0.6m may be advised.

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