A Hydraulic Comparison between Center Pivot Irrigation Traditional and Modern Type ANABIB

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ABSTRACT—The objective of this article is to realize a hydraulic comparison between the traditional and modern irrigation pivot system (Type ANABIB). This comparison is based on evolution of hydraulic parameters like pressure, flow and length between the sprinklers (nozzles) to obtain a homogeneous distribution of water over the entire irrigated area. Center Pivot irrigation has an important agricultural component in Algeria, especially in the South such (El Oued, Ouargla, Biskra, Meniaa, Adrar, etc.). However, this irrigation technique is often used by farmers, who don't have the scientific expertise to develop and improve the performance of their equipment, taking into account the weather conditions of desert areas, as well as the sizing of the pumping system. Farmers in Souf deal with the traditional pivot system and don't accept the modern type ANABIB with suitable normalization factor because its high cost. Therefore, the necessity to improve hydraulic performance of the traditional system until it has a high normalization factor and good uniformity of irrigation. However in well-designed devices we can get a good hydraulic efficiency the order of 85%. The results of the work observed for the hydraulic parameters of traditional system commonly used by farmers give us 59,58 and 70,76% of Cuh that values gives us the possibility to improve its uniformity of irrigation by the predominant effect of the sprinkler distance to get an acceptable values of normalization factor (over than 85%), on the other hand ANABIB system gives 95,98 and 97,28% of Cuh that considers as a perfect values . It is intended that this article be served as a starting point from which improved uniformity may be developed in the future.

Keywords —Hydraulic performance, nozzles, pumping system, irrigation system...

I. INTRODUCTION

Center pivot irrigation plays a major role in many agricultural practices throughout Algeria especially on the south of the country as many farming regions do not receive consistent and adequate rainfall. Therefore center pivot irrigation (sometimes called water-wheel or circle irrigation) is a method of crop irrigation in which equipment rotates around a pivot and crops are watered with sprinklers, however a circular area centered on the pivot is irrigated. Also this system has experienced a wide diffusion worldwide because of its advantages relative to other irrigation systems such as: high potential for uniform and efficient water applications for example when the system is properly designed and managed more than 90% of water applied can be utilized by the crop; high degree of automation, which allows applied precision farming practices including variable rate technology; and the ability to apply water over a wide range of soil, crop and topographic conditions[1,11]. A main disadvantage is high water application rates; irrigated area needs to be free of obstacles, Requires more pumping energy with better water filtration; wind speed when have exceeded 3 m/s increases heterogeneity of the pluviometer and the set up costs can be high. Efforts to improve center pivot design and management have concentrated on increasing water application uniformity, controlling negative environmental impacts such as excessive water and fertilizer operational losses and in this work we want to show that we can improve irrigation performance without increasing in the energy in relation to the amount of water use. Center pivot irrigation is a form of overhead sprinkler irrigation consisting of several segments of pipe (usually galvanized steel or aluminum) with sprinklers positioned along their length, joined together and supported by trusses, and mounted on wheeled towers[2]. The machine moves in a circular pattern and is fed with water from the pivot point at the center of the circle. Center pivots are typically less than 500 meters in length (circle radius) and the most systems today are driven by an electric motor mounted at each tower but sometimes replaced by hydraulic system. There are a study includes the diagnosis of field operation of a swivel ramp, mechanized spraying system in use and in good working order adopted by the Agricultural Development Corporation(SMVDA) El Khir, delegation of M'Hamdia, Governorate of Ben Arous (northern Tunisia) and to appreciate the quality of the irrigation carried out[14]. This study and our study are the same goal; this goal is to affect the evaluation of the pluviometer distribution and the coefficient of uniformity but with different pivot systems and different weather conditions too. We try to compare the uniformity coefficient of the artisanal and modern center pivot irrigation systems, the results of this comparison allows to modify the design of traditional pivot on the future and that is the present of this article.

II. MATERIALS AND METHODS

2-1) System description

2-1-a) Traditional irrigation pivot system

Various sprinkler irrigation methods and installations whether, fixe or mobile, have been tested in recent decades to satisfy the farmer's needs. The commonly used and least expensive system for irrigating small and medium-sized farms is the traditional irrigation pivot system with low to medium operating pressure (2 – 3, 5bar). This system combines some characteristics permanent and semi-permanent of installations, as the sprinklers operate at low or medium pressure, the system can be classified as a low or medium pressure installation, semi-permanent and with manual movement. It is recommended for irrigation crops with total coverage such Lucerne, corn, cotton, potato, carrot and the peanut or the groundnut, In this work the traditional pivots is just the artisanal center pivots was made by local craftsmen to irrigate potatoes and with these artisanal machines farmers produced more than 1 million tons of potatoes in more than 35000 artisanal pivots, which represents 35% of the national production for an estimated price 360 millions €, on 2014[13]. The pipe and the towers are typically galvanized to prevent corrosion. Experimentation is done on a artisanal pivot located in the region named El OGLA, Robbah, city El Oued. Discloses a traditional irrigation pivot system including a drive unites or drive towers that is the part of the machine that touches the land and contains the necessary components for the machine to move; A lot of sprinklers atomizer with low pressure and sprinkler is a device that sprays water, the sprinkler used in this artisanal pivot highlight in the following picture.

Fig.1. Sprinkler of traditional irrigation pivot system.

The system includes also four spans (The long pipes between drive units) with 12 meter in length and 56 mm in diameter, spans consist of the main water pipeline, sprinklers, and a supporting structure of trussing that holds the weight between towers and the pivot point that anchors the machine to a permanent location in the field. Figure.2. Shows the traditional pivot system used in this study.

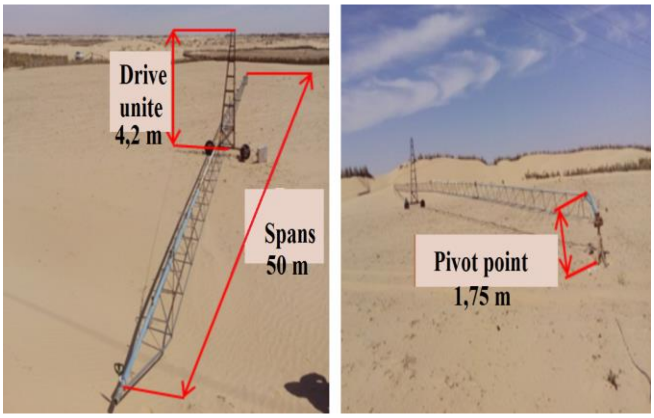

Fig.2. Traditional irrigation pivot system [12].

2-1-b) Modern pivot irrigation system type ANABIB

Center pivots are mechanical irrigation systems that automatically revolve in a field to apply irrigation water through sprinklers, divers main components make up a center pivot. Each part is responsible for the movement, control, or structure of the machine. this work concerns with a modern pivot system located in the region named El Hadjira, Ouargla town to irrigate barley, this system named 160 EL is electrically powered, using a public power source and it made up of six drive unites each one is powered by 0,74 KW[3] and much of modern sprinkler sprays water similar of rainfall, the modern sprinkler used in this system highlight in the next picture.

Fig.3. Sprinkler of modern pivot system type ANABIB.

This system constitutes of a number of spans which vary are from 52 meters in length and around 3,7 meters in height, that are connected and rotate about a central fixed point or pivot point. Refer to figure 4. Water is supplied to this system through the pivot point. Each span is propelled by a small electric motor. For a typical 312 meter long system the rotation or speed is 123 m/h. The rate of water supply to the system is depended on the pump rate and the design of the system. However, the water application rate increases along the pivot spans as it digresses outwards from the center [9].

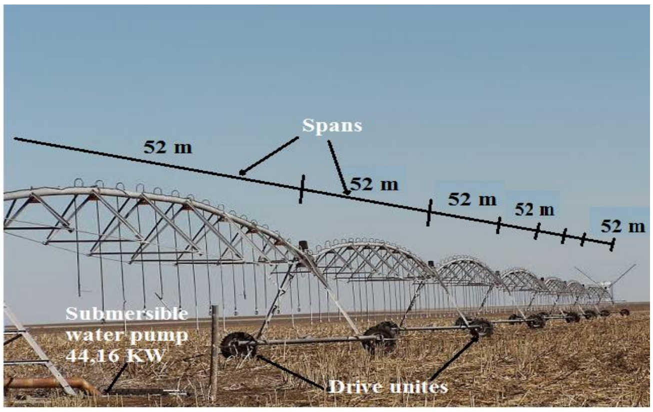

Fig.4. Irrigation pivot system type ANABIB.

Due to the spans rotating in a circular motion around the central pivot, irrigation is formed in a circular motion; therefore, the corners of a square field can often be left un irrigated. These pivot ANABIB systems are suitable to irrigate most crops and have been developed to irrigate barley in the south of our country. In Algeria, Adrar and

Ouargla are the best towns equipped by this kind of irrigation systems. The table 1 highlights the main characteristics of 160 EL system used in El Hadjira.

Paramètres	Caractéristiques
Radius watered, y beyond the edges	312 m
Area watered in full circle	32.96 ha
Kind of Span	52 m
Tube diameter	160 mm
Height of construction	3,7 m
medium height of sprinklers compared to the land	1,3 m
Watering capacity	0,93 à 1.39 l/s/ha (soit 8 à 12 mm/j)
Total water consumption	69,6 m^3/h- 104,4 m^3/h
Hour of service during a day	24/24h
Max speed drive unite	123 m/h
Minimum time of rotation	12 h 10 mn
Pluviometry mini. of rotation	4-6 mm
Feed pressure admission pivot	1,7-1 ,8 bar
Pressure sprinkler at last connection	1,2 bar
Pressure exercised on the land	13 N/cm^2
Voltage	380 v
Generator power required	10,5 kVA
Absorbed power of the public network	7,2 kVA

Table 1: highlights the main characteristics of 160 EL systems[4].

2-2) Experiment Setup

In this paragraph, we will try to present the results of the experimental measurements to compare the hydraulic performance of the two studied systems, the determination of the power pump and the dimension of the pipeline are required. In the first step, the experimentation consists to measurements and observations of spatial pluviometer distribution of two pivot systems considered on the main places. This study of the pluviometer distribution below the different sprinklers along the ramp installed in a fixed position, the study is according to the various parameters like flow and pressure. These pluviometers are only the identical plastic cups with 140 ml in the capacity for the single. The inlet diameter of the plastic cups is 70 mm and the reception space is 38,46cm^2.

2-3) Test procedures

On account of the fixation, the cups are buried 1/3 of its height. The medium wind speed is 10 Km/h that considered suitable (less than 3,5m/s[10]). We put a pluviometer every two (02) meter separately in two lines for traditional pivot and every twelve (12) meter separately in two lines too for modern ANABIB pivot. The choice of two lines is: to avoid the measurement errors and the effect of the wind on the results; to validate the different results and to discover the anomalous values. In the case of center pivots, the **Hermann** and **Hein**'s Uniformity Coefficient (Cuh) is the commonly used coefficient. The most frequent interval of uniformity is between 80 and 85%. In 30% of the machines, the Cuh is lower than 80%. All these center pivots have design problems and in a number of cases, management problems have been identified as well. Normally, these traditional machines require an adequate design [13]. Cuh is the ratio of the sum of the absolute value of difference between every water depth and average water depth of all observation points to the average value of all water depths, which can better display the condition of the water distribution and the average deviation in all fields. Cuh is calculated with Equation (1) [6,7]:

$$Cuh = 100\left(1 - \frac{\sum_1^n \left(r_i \left|X_i - \frac{\sum_1^n r_i X_i}{\sum_1^n r_i}\right|\right)}{\sum_1^n r_i X_i}\right) \quad (1)$$

where, Cuh is **Herman-Hein** uniformity coefficient, %; n is the total amount of rain gauges used for the series in place; i is ordinal number of rain gauges; i=1 when the adopted rain gauges were closest to the center pivot and i=n when the adopted rain gauges were furthest away from the center pivot; X_i is the sprinkling irrigation water depth of the rain gauge (mm) and r_i is the distance between the rain gauge and the center support (m).

III. RISULTS AND DISCUTION

The figure 5 below shows an important irregularity of pluviometer for the traditional pivot especially from the center to twenty (20) meter, after that it commences to regulate at general case.

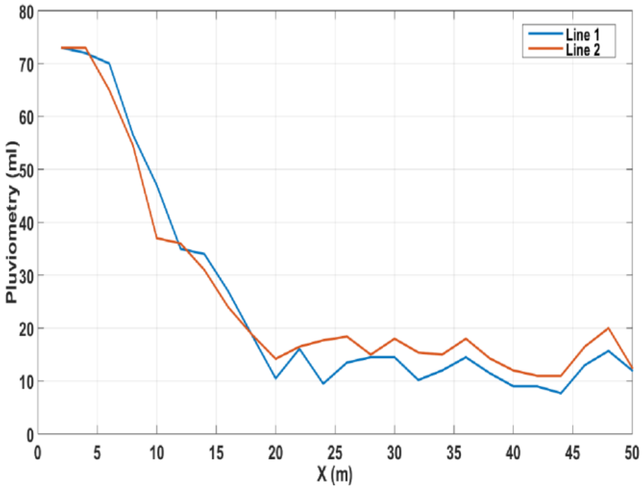

Fig.5. Pluviometry recordings for spraying of traditional system[2].

On the other side, the figure 6 shows that the ANABIB pivot system starts with medium rate of pluviometer but, with low interval along the ramp until 300 meter then, the rate pluviometer becomes very low.

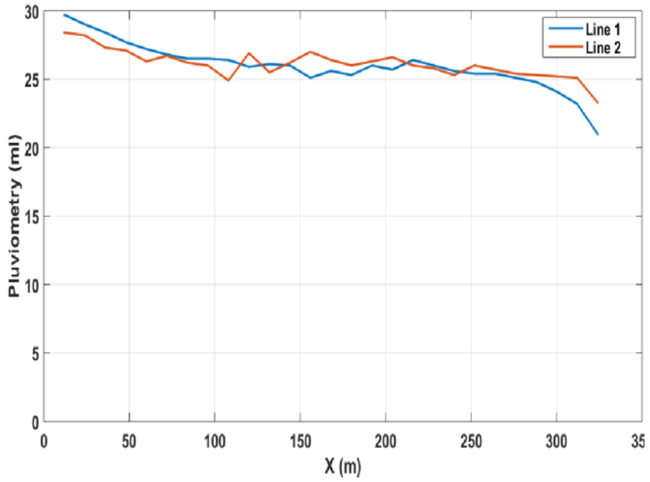

Fig.6. Pluviometry recordings for spraying of ANABIB system[5].

Now, we will evaluate the pressure of pipe length. Figure 7 shows that the pressure is decreasing until 25 meter from the center then, it's practically a stable value. In Figure 8 we clearly notice that the pressure is constantly decreases and approaches to get a straight line in shape. After 170m from the center of pivot the pressure is lower value of 1,2Bar that is a value negatively affects in performance of the irrigation system, on the rest of distance.

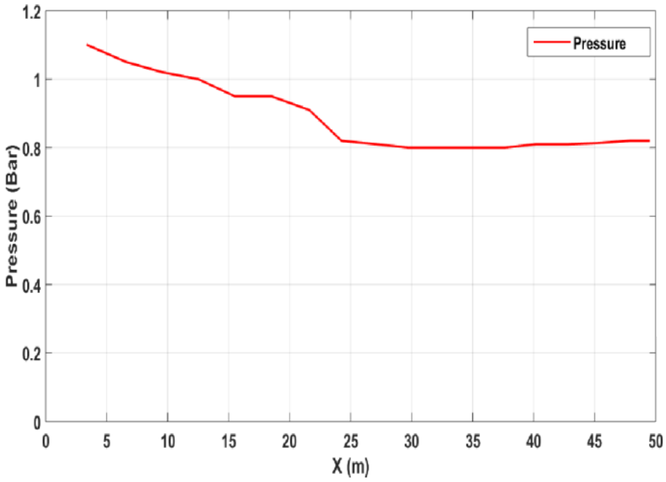

Fig.7. Distributions of pressure along the ramp for traditional system[2].

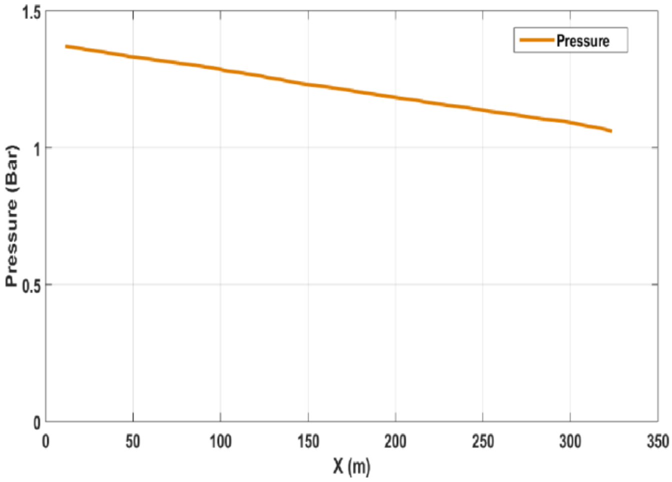

Fig.8. Distributions of pressure along the ramp for ANABIB system[5].

Figure 9 and 10 shows the flow variations along the pipe at the sprinklers. We observe the same remarks that we have previously on pressure.

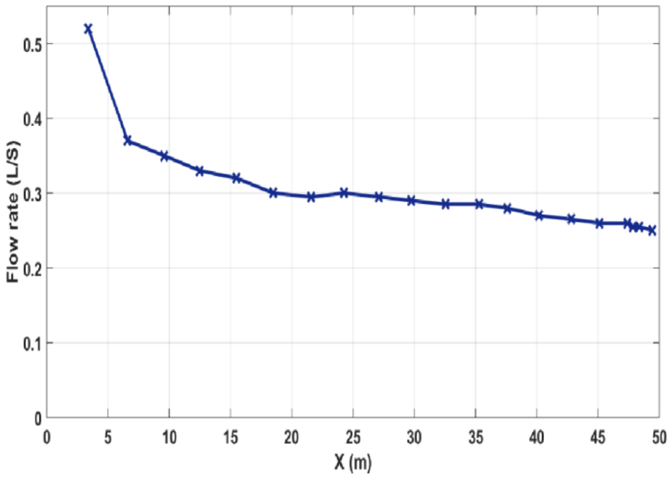

Fig.9. Distributions of flow rate for traditional system [2]

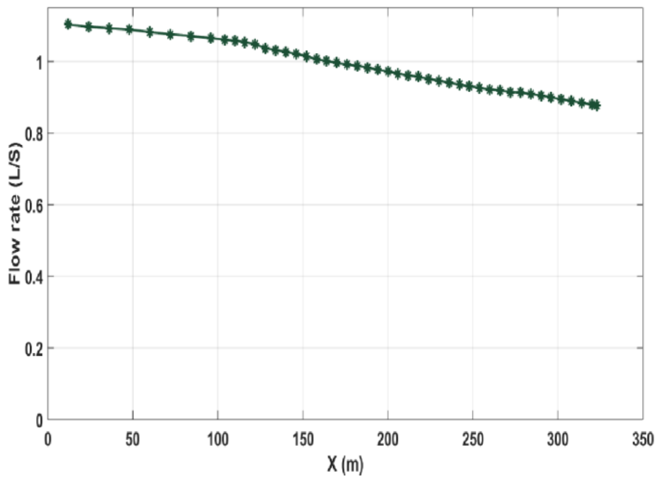

Fig.10. Distributions of flow rate for ANABIB system[5].

The next picture shows the distribution of flow rate in the ramp at a distance r from the pivot.

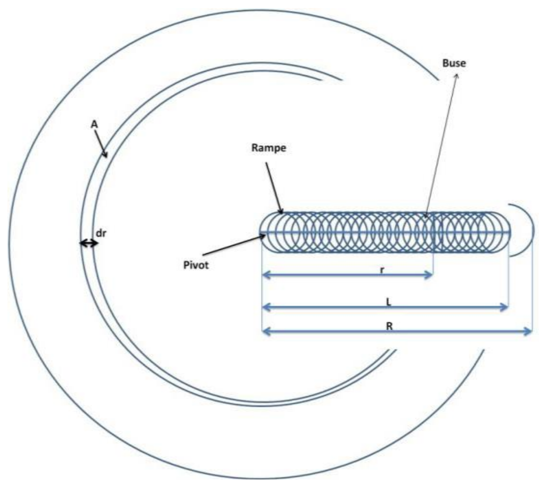

Fig.11. Pulverization by pivoting ramp

The test of repeatability of Cuh for the two systems on observed the results indicated on the Table 2.

Type de pivot	Cuh	
	Ligne 1	Ligne 2
Traditionnel	59,58	70,76
ANABIB	95,98	97,28

Table 2. The uniformity coefficient of the two systems studied.

This result highlights the predominant effect of construction on the expected variability of irrigation. Indeed, in these two systems, the evolution of hydraulic characteristics are deffirents. This deffirent may explain a low spatial variability (uniform irrigation). The figure below shows a comparison of the uniformity coefficient between lines.

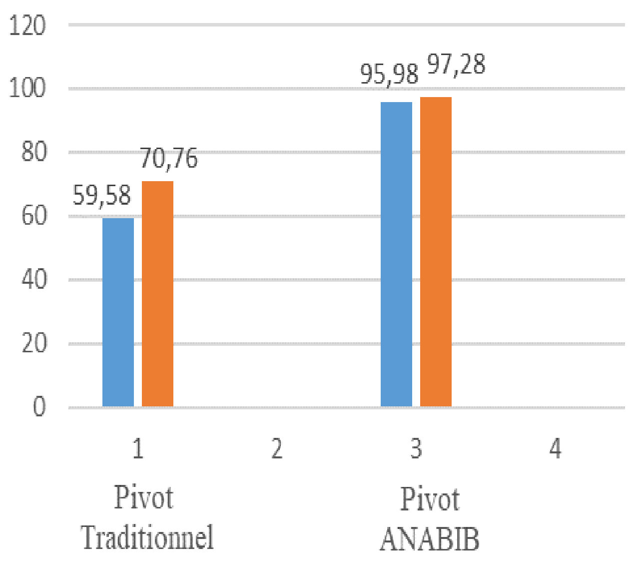

Fig.12. Histogram indicate the uniformity coefficients of the two systems studied.

Noted that the international standards, which stipulate the normalization factor is over 85%.

IV. CONCLUSION

Irrigation with centre pivots has increased exponentially under the last decade in Algeria; Center-pivot irrigation systems have experienced a wide diffusion worldwide because of their advantages relative to other irrigation systems. The design development of the various components allows a uniform application of water. The flow rate sprinkler along the pipe is not the same from one to the other that effect to the uniformity of irrigation. To conduct performance evaluations of the center pivots we selected a representative sample of the two systems traditional and modern used in south of Algeria. Uniformity tests of the systems were conducted according to the same topographic conditions such wind speed, the sandy earth and inlet flow rate. The uniformity coefficient of **Hermann** and **Hein** (CUh) of 02 systems reached acceptable values (over than 85%) for ANABIB system, while the traditional system, spatial uniformity of irrigation may be questioned, because we obtained very low coefficient values (59 to 71%) but although these results for the artisanal center pivot, farmers deal with it give a huge product (35% of national product). Therfore, we require to modify the design of the dominant system (Traditional pivot) to improve its uniformity of irrigation by two methods: the first is to change the diameter of sprinklers with keeping the same distance between the nozzles and the second is the predominant effect of the sprinkler distance with keeping the same diameter of nozzles until we get an acceptable value of normalisation factor (over than 85%) and all that what we will looked for the rest of our stady.

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