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Comparative performances of mechanized water spraying systems: Single and combined frontal ramps (swivel / frontal)

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Abstract. The present investigation consists of diagnosing the field operation of a frontal ramp, a simple system of mechanized sprinkling of water, exploited in the governorate of Beja (North-West of Tunisia) and a combined ramp (pivot- Frontal) system, which ensures of these two modes of mechanized spraying, used in the governorate of Manouba (North of Tunisia), and to assess the quality of the watering carried out during their first harvest. This work has particularly affected the comparison of the rainfall distribution of the water and the coefficient of uniformity of each system with respect to the other as follows: single frontal ramp with combined frontal mode, in the wind speed ranges and Operating pressures relatives. The operating diagnosis showed that the two machines are in good condition and capable of achieving a good rainfall distribution (Cu > 85% in strong wind). The comparative performance study found that the simple front-end system is less sensitive to wind and less energy-demanding compared to the combined front-end mode. Certainly, the subsequent use of a simple mechanized sprinkler system is an adequate solution, considering also its good efficiency compared to a combined mechanized sprinkler system.

Keywords: Mechanized spraying, single front ramp, combined ramp (swivel-front), rainfall distribution, coefficient of uniformity.

1. Introduction

Water remains the main constituent of living beings and the essential element of all life forms. Without water, no plant can live. But it does not always rain at the right time, which influences crop yields and results in financial losses. Irrigation has long been an essential component of agriculture. The greatest progress in agriculture has been achieved by this component [1]. Globally, the irrigated sector provides 30% of all agricultural production [2]. In Tunisia, this sector accounts for 32% of total production [3].

The limit of water resources and the growth of their demand supply the debate on the problem of improving the efficiency of use and the productivity of water [4]. The farmer needs to look for the irrigation method that attributes high yields, improved harvest quality, and reduced water and energy consumption [5].

Spray irrigation is widespread in several parts of northern and central Tunisia. It continues to develop mainly with financial incentives to save irrigation water [6].

The technical evolution of sprinkler irrigation systems has been influenced by the desire to save labor and to reduce the hardship of labor [7]. In the beginning, it was a system of manual displacement pipes with vertically mounted sprinklers, finally orienting themselves towards the design of sprinklers, such as mechanized sprinklers [8].

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The swing ramp and front ramp systems are mainly used on large farms. They have a programmable drive mechanism, which serves to move the elements [9]. Faced with the constraint of area and irrigation performance, several combinations between these machines were made. The combined ramps are hybrid devices between the pivot and the front ramp, capable of moving in both rotational and translational water [10].

The aim of this study is to compare the performances of a single machine (frontal ramp) and the frontal mode of a combined machine (swing-frontal ramp) adopted in the Governorate of Beja (North-West of Tunisia) and the governorate of Manouba (Northern Tunisia).

2. Material and method

2.1. General presentation of study sites

The study of the frontal ramp simple was carried out in the Company of Dairy Farms (CDF), based at the delegation of Medjez El Bab, governorate of Beja (North-West of Tunisia), while that concerning the combined ramp (Swivel-front), was carried out in a large private operation, located in the delegation of Bourj El Amri, governorate of Manouba (Northern Tunisia).

The geographical and climatic characteristics of the two experimental sites are shown in Table 1.

Table 1. General framework of the study

	Single front ramp	Combined ramp (swivel-front)
Use campaign	First	First
Experimental site	CDF	Large private operation
Delegation	Medjez El Bab	Bourj El Amri
Governorate	Beja	Manouba
Location		
Environment	In the North, a humid climate and in the South, a rather dry climate [11].	Mediterranean region belonging to the upper semi-arid bioclimatic stage [13].
Mean temperature	Between 15 ° and 19 ° C from South to North [12].	18,7 °C [14].
Average rainfall	In the South: between 350 and 450 mm [12].	450 mm [14].
Wind	Among the most windy areas of the national territory. Dominant winds from North and Northwest direction [12].	Blowing mainly from the west to the northwest and responsible for the frequent precipitation during the winter period [13].

2.2. Technical description

The study was carried out on a simple frontal ramp, branded "VALMONT" and a combined ramp (swivel-front), brand "BAUER", whose technical characteristics are presented in Table 2.

The Figure 1 illustrates the construction diagram of the combined ramp (pivot-front). The frontal ramp has the same design principle; however, it differs essentially in its bus layout and mode of travel.

Table 2. Comparative technical characterization of the mechanized spray ramps studied [15; 16]

System studied	Simple Frontal Ramp	Combined Ramp (swivel-front)
Main specificity	sprinkles a rectangular plot and advances in translation	Able to water by turning like the pivot or in translation like a frontal ramp
Brand & Origin	VALMONT & USA	BAUER & Australia
Central Tower	Linearly displaceable	Movable
Length of system (m)	300.00	223.50
Length of field irrigated (m)	2700.00	230.20
Pipe diameter (mm)	168.00	168.00
Length of cantilevered (m)	25.08	11.70
Length of span (m)	54.80	52.80
Number of nozzles	102	74* ; 37**
Number of spans	5	4
Spacing between sprinklers (m)	2.88	2.93* ; 5.86**
Cane of downhill flexible	Distance to ground: 2.00 m	Distance to ground: 3.10 m
Total feed rate (m^3/h)	180.00	84.20
Operating pressure (bars)	2.70	2.70
Maximum travel speed (m/h)	123.80	105.00* ; 125.00**
Ramp guidance	By furrow	By furrow

**: Front Ramp Mode; **: Pivot Mode*

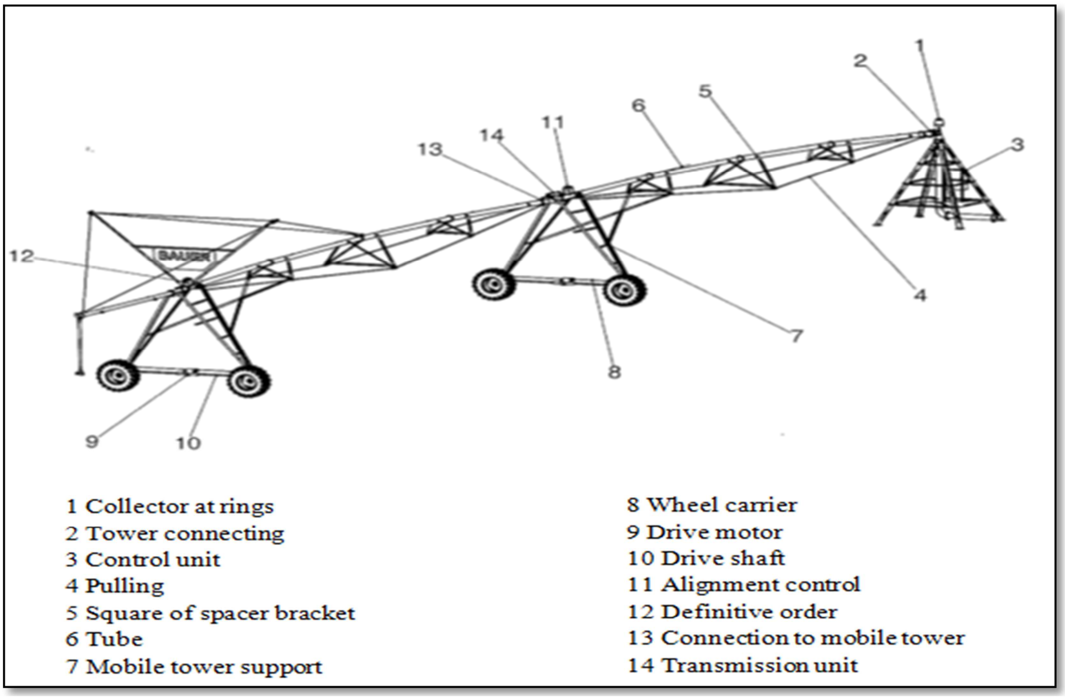

Fig.1 Technical description of the combined ramp ([17]; Adapted)

2.3. Determination of rainfall distribution

The tests were conducted with new equipment during his first employment campaign. They were undertaken under conditions in accordance with ISO 11545 [18] and the experimental recommendations of the CEMAGREF concerning the calculation of mean rainfall. During the tests, the anemometer, indicating the wind speed and direction, was installed at a height of 2 m within a radius of 200 m from the study site. The wind speed is the average of a measurement for 30 s, and its direction is given every 10 mn.

Measurement of rainfall was accomplished by varying two parameters, namely wind speed and operating pressure, which have a major influence on irrigation uniformity. Indeed, the most important factor to be taken into account in the evaluation of water losses is the transport by the wind out of the irrigation zone or drift. Drift can lead to losses of up to 40%, as the aggravating wind effect is most noticeable at a speed of 4.5 m/s [19], due to a likely change in the size of Drops [20].

The containers used to collect the volume of water delivered are 18 cm in diameter and 17 cm high, arranged as shown in Fig. 2 along two irrigated transverse lines (2.5 m × 2.0 m).

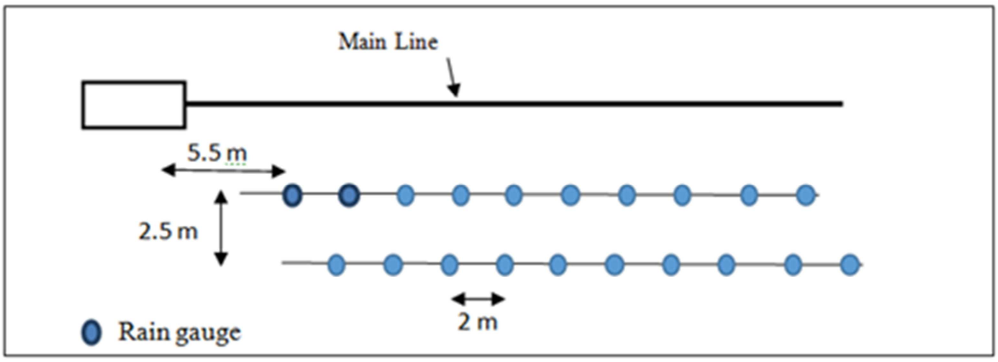

Fig.2 Experimental arrangement of rain gauges under the frontal ramp according to ISO 11545 [18]

The mean rainfall P is calculated by the following formula:

$$P = 10 V / S$$

With:

P: Rainfall (mm)

V: Volume of water collected per vessel (cm^3)

S: Top section of container (cm^2)

2.4. Calculation of uniformity coefficient

The evaluation program for a pressure irrigation system (sprinkler or drip) is mainly based on the determination of a performance index: uniformity of water distribution [21] or efficiency of uniformity. The efficiency of uniformity describes the spatial homogeneity of the irrigation dose with respect to the irrigated area [22].

Several parameters have been proposed to express in a synthetic way the quality of the results obtained from the experimental measurements, but according to Tiercelin and Vidal [23], only one of these parameters, although very old, is used in all countries. Is the uniformity coefficient (Cu) of Christiansen.

The uniformity under the second span of the spray booms is assessed by Christiansen's formula [24], which was the first to study uniformity of distribution by means of a coefficient of uniformity.

$$Cu = 100\left[1 - \left[\sum_{i=1}^{i=n}\left(\frac{|Vi - Vm|}{Si}\right) / \sum_{i=1}^{i=n}\left(\frac{|Vi|}{Si}\right)\right]\right]$$

With:

Cu: Coefficient of uniformity (%)

Vi: Volume of water harvested in container i (cm^3)

Vm: Average volume of water in n containers (cm^3)

Si: Upper section of container i (cm^2)

Generally, ensuring a uniform distribution of water is a rather delicate task for several reasons, including:

* In order to circumscribe the variation of the flow along the ramp within an acceptable range, Christiansen proposes to limit the length of the ramp to a value such that the pressure variation (ΔP / P) does not exceed 20% [25];

* The presence of plants on the plot modifies the uniformity of the distribution of water according to Seguier [25];

* The angle of the jet may vary from one station to another, due to the variation of the verticality of the sprinkler in case of rough terrain [26];

* Uniformity is dependent on the rate of overlap, wind direction and wind speed.

3. Results and discussion

3.1. Assessment of rainfall distribution

Usually, a front ramp is equipped with the same type of nozzles and a combined ramp has a double bus, one operating in pivot mode and the other in frontal ramp mode, by means of solenoid valves. Nevertheless, in the case under consideration, the combined ramp is equipped with a single bus dual function bus. The basic nozzles are those of the pivot. Thereafter, nozzles have been fitted (which may be called adaptations) fitted with solenoid valves, which open during frontal ramp operation.

In both cases of operation of the combined machine (pivot-ramp front) studied, the nozzles are in good working order, since the nozzle flow rates of the manufacturer and those measured have a small deviation, usually attributed to Measurement errors. About the single front ramp, all nozzles provided similar flow rates.

Compliance with the manufacturer's design plan and the adoption of an appropriate maintenance program, at least once a year [27], ensure that the mechanized spraying systems used are functioning properly, and possibly, to improve the uniformity of irrigation water distribution [28].

3.2. Effect of wind on irrigation quality

Wind is a major disturbance factor. At the level of an individual sprinkler, the spatial distribution of the water can be strongly deformed. In general, there is a marked increase in the maximum rainfall, and a decrease in the wetted area [29]. The effect of wind on irrigation uniformity is less pronounced for other sprinkler systems. According to James and Blair [30], uniformity would tend to increase with wind speed as long as it does not exceed 4 m/s.

In the case of the combined ramp frontal mode, the incidence of wind speed on the same pressure rainfall distribution (Table 3) showed a drop in rainfall in the case of a strong wind, while Simple frontal ramp operation is slightly wind sensitive.

Table 3. Effect of the variation of the wind speed on the rainfall distribution under the two ramps considered

Tests with constant pressure	Rainfall distribution	
	Low wind	Strong wind
Frontal mode of combined ramp	Homogeneous with an average dose of 10 mm	Dispersed between different irrigated areas
Single frontal ramp	Homogeneous with an average dose of 15 mm	Relatively homogeneous, while moving slightly away from the average dose

The coefficient of uniformity, in the case of the frontal mode, deteriorated considerably as a result of the increase in wind speed. The degradation (of the order of 7%) is considered small (Table 4). In the case of the single frontal ramp, the Cu experienced a smaller decrease of about 5% (Table 4). In both cases, irrigation can be continued with a uniform coefficient of uniformity, which gives the possibility of irrigation even with a slightly higher wind speed, which is in line with the test standards of the CEMAGREF (80% to 95%).

Table 4. Effect of the variation of the wind speed on the rainfall distribution under the two ramps considered

Tests with constant pressure	Coefficient of uniformity (%)	
	Low wind	Strong wind
Frontal mode of combined ramp	90.3	86.3
Single frontal ramp	94.8	89.6

In conclusion, it can be concluded that a frontal ramp of a combined machine is more sensitive to the wind with respect to an independent frontal ramp, since a degradation of the coefficient of uniformity is greater for the first type. Also, the uniformity index in wind conditions for a single frontal ramp is higher than that of a combined frontal ramp.

3.3. Effect of operating pressure on irrigation quality

Generally, an increase in operating pressure results in an increase in the delivered volume.

The results of the rainfall distribution revealed that the variation in pressure has practically no effect on the average rainfall delivered by the two types of mechanized spraying machines. This could also be explained by the existence of a pressure regulator at each nozzle.

However, in the case of the single frontal ramp, the increase in pressure leads to an increase in the coefficient of uniformity from 93.5% at a pressure of 1.8 bars to 96.7% at a pressure of 3.5 bars (Table 5). On the other hand, in the case of the combined mode, this increase gives rise to a slight influence on the coefficient of uniformity.

It can be said that the simple frontal ramp is the least demanding in terms of energy, since the coefficient of uniformity remains enormously high even with a low operating pressure of the order of 1.8 bars.

Table 5. Effect of the variation of the operating pressure on the coefficient of uniformity for the two ramps considered

Tests in calm weather	Coefficient of uniformity (%)	
	Low Pressure	Higher Pressure
Frontal mode of combined ramp	89.0	90.7
Single frontal ramp	93.5	96.7

4. Conclusion

The mechanized ramps of water spraying have become more and more usual in Tunisia. With regard to the knowledge of their characteristics, their principles of operation and to master their use, one must appreciate the performance of each in relation to the other. The study undertaken on the two types of simple and combined sprinkler machines showed that the frontal ramp is generally capable of providing an ample uniform irrigation. In addition, a single front ramp works better than a combined ramp because of its less sensitivity to wind speed variation and less energy requirement. Overall, a simple sprinkler is more efficient than a combined machine.

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