# HOSE-DRAWN TRAVELER WITH A LINE OF SPRINKLERS, AN ALTERNATIVE TO THE GUN-SPRINKLER TRAVELER SYSTEM.

# ENROULEUR AVEC UNE RAMPE PORTE ASPERSEURS, UNE ALTERNATIVE AU CANON AUTOMOTEUR

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## ABSTRACT

Traveling sprinkler systems usually use a large volume gun-sprinkler that requires high operating pressures. These sprinklers deliver water at high application rates with large drops that can damage some plants and can also destroy soil surface structure, in some cases leading to surface sealing which reduces soil infiltration causing runoff. They can also be characterized for having low uniformity applications, especially in windy areas.

The use of a line with medium or low-pressure sprinklers, mounted in the system-moving vehicle, instead of the gun-sprinkler, can be an alternative to the use of traveler systems in some crops and topographic conditions. The smaller sprinklers require less operating pressure, apply water with smaller drops and their overlapping can increase the irrigation uniformity.

Field tests were made to evaluate the performance of the traveler machine with a line of four sprinklers (250 kPa) and a gun-sprinkler (350 kPa), with three different travel speeds, corresponding to three different application depths, and different wind speeds.

In windy conditions, with wind speeds between 1,4 and 4,0 m/s, and a single pass, the irrigation events with the line of sprinklers produced more uniform irrigation events, especially in the low quarter, than the gun-sprinkler. Evaporation and wind drift losses were slightly higher with the line of sprinklers, although these events had higher potential application efficiency.

The systems performance can be increased with the overlapping of the irrigated strips, with similar increments for both system options.

## RÉSUMÉ ET CONCLUSIONS

Les systèmes d'arrosage au déplacement utilisent d'habitude un canon arroseur a grand volume qui exige des hautes pressions de fonctionnement. Ces arroseurs livrent l'eau a des élevées taux

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d'application et aux grandes goûtes, qui peuvent endommager les feuilles des cultures les plus sensibles. Comme ces goûtes portent une grande énergie cinétique, elles peuvent également détruire la structure extérieure du sol, induisant la formation des croûtes, qui réduisent l'infiltration, provoquant le ruissellement et l'érosion. Ces systèmes peuvent également se caractériser par des basses valeurs d'uniformité d'application, particulièrement si les vents sont forts.

L'utilisation dune rampe porte asperseurs à moyenne ou basse pression montée sur le système véhicule, au lieu du canon arroseur, peut être une alternative en permettant l'usage des systèmes de voyageur sur quelques cultures et conditions topographiques. Les arroseurs, plus petits, exigent moins de pression de fonctionnement, appliquent l'eau aux goûtes plus petites, leur recouvrement pouvant augmenter l'uniformité d'irrigation.

Des essais sur le terrain ont été faits pour évaluer les performances de la machine a voyageur avec une ligne de quatre arroseurs tournant en secteur 180º. L'abouche des arroseurs était de 9 millimètres en diamètre et la pression de fonctionnement était de 250 kPa. Pour comparaison, on a essayé aussi le même système enrouleur équipé d'un canon arroseur a la bouche de diamètre 16 millimètres et pression de fonctionnement de 350 kPa. Les essais ont été faits a trois vitesses de déplacement, correspondant à trois différentes hauteurs d'applications, et différentes vitesses du vent.

Dans des conditions venteuses, les vitesses du vent étant entre 1.4 et 4.0 m/s, et avec une seule passage, les événements d'irrigation avec la rampe aux asperseurs étaient plus uniformes (53%< CU < 80%), particulièrement dans le quart inférieur (19%< DU < 71%), que ceux du canon arroseur (28%< CU < 75% et 5%< DU < 53%). L'uniformité d'irrigation dans les événements avec la rampe aux asperseurs moyenne pression était très semblable pour toutes les vitesses de déplacement, mais avec l'option canon arroseur elle diminuait quand la vitesse de déplacement augmentait. En comparant les deux options du système, l'effet du vent sur l'uniformité d'irrigation est plus important sur canon arroseur, qui présente des plus petites valeurs de CU pour la même vitesse du vent (Figure 2).

Les pertes d'eau dues a l'évaporation et a la dérive du vent sont plus hautes si les vitesses de déplacement sont inférieures, quand c'est plus long le temps d'application et plus haute la sensibilité aux effets du vent. Le canon arroseur est moins affecté par le vent parce que l'application ce fait aux grandes goûtes, a l'énergie cinétique plus importante, en résistant mieux a la dérive du vent. Ci bien les pertes par évaporation et par dérive du vent ont été plus élevées avec la rampe aux arroseurs, cette option a eu des valeurs potentiels plus élevés pour l'efficience d'application (PELQ) sur toutes les vitesses de déplacement, par comparaison avec le système au canon arroseur (8% < PELQ < 71% pour la rampe d'aspersion, 3% < PELQ < 36% pour le canon arroseur). Les valeurs de PELQ sont bas pour la plupart des événements d'irrigation aussi a cause de la basse uniformité d'irrigation.

Le chevauchement des bandes irriguées adjacentes peut être une solution pour augmenter les performances d'irrigation. Pour les deux options, 25 % de recouvrement des bandes adjacentes peut produire une augmentation moyenne des performances (uniformité et efficience) d'irrigation de 12 à 14 %.

## INTRODUCTION

The hose-drawn travelers are irrigation machines that usually use a large rotating gun-sprinkler, with high operating pressure requirements, that can irrigate large areas. It's an irrigation system that can be easily adapted to different soils, crops and topographic conditions, has great mobility, allowing it's use in farms with small and irregular irrigated areas, and represents a low investment cost by hectare, which makes it a extensively used system.

However, it also has some disadvantages: a low distribution uniformity, the need for high operating pressures, distribution of water with big droplets (causing problems to soil structure and to the crop, due to droplet impact, that can be quite severe), and water application intensities sometimes incompatible with soil infiltrability. The distribution uniformity is affected by changes in wind speed and/or direction, sprinkler characteristics (jet trajectory, nozzle type, etc), and variations in operating pressure and traveling speed.

The use of a line of sprinklers, generally with low or medium pressure, instead of the gun-sprinkler is an attempt to improve the performance of these systems. Normally, these smaller sprinklers are less affected by wind conditions and can generate more uniform irrigation events. The low-pressure sprinklers tend to have higher application rates that can represent a problem to soils with low infiltrability. Thus, the use of medium pressure sprinklers can be a better compromise between the need to reduce pressure and, at the same time, to have application rates more compatible with soil intake characteristics. However, it should be noticed that this option also has some important disadvantages as related to the gun option: it requires more labor to move the equipment and put it to work; furthermore, this equipment is not easily used with maize and other tall crops.

The main goal of this study was to evaluate the performance of a hose-drawn traveler with a line of four medium pressure sprinklers and to compare it with the performance of the same machine with a gun-sprinkler.

## MATERIALS AND METHODS

Field tests were made in Southern Portugal, between June and September 2002, in a field with a clay soil on undulated topography, with slopes ranging from 0 to 3 %. The hose-drawn traveler had a 63 mm diameter and 270 meters long polyethylene hose, and was tested with two system options: a) a 25,2 m line of sprinklers (Figure 1), with four 180º rotating sprinklers, with a 9 mm nozzle and an operating pressure of 250 kPa; and b) a gun-sprinkler, with a 16 mm nozzle and an operating pressure of 350 kPa. The distance between the bottom of the line of sprinklers structure and the soil was 1,1 m, and the sprinklers were 1,8 m above the soil surface. They were spaced approximately 8 m from each other and had a wetted diameter of 34 m, allowing the irrigation of a 59,2 m wide strip using a total flow rate of 19,2 $m^3$/h. The gun-sprinkler had a wetted diameter of 60 m with a flow rate of 17,9 $m^3$/h.

*Figure 1. Hose-drawn traveler with a line of sprinklers (Enrouler avec une rampe porte asperseurs).*

The traveling speed of the moving vehicle along the field depends on the reel rotational speed, in this case commanded by a partial flow turbine mechanism that uses part of the flow to make the reel rotate. Since the line of sprinklers structure was heavier than the gun-sprinkler, it was necessary to increase the flow rate that passed through the turbine mechanism to achieve the same traveling speed. This and the need for more total flow rate in the line sprinklers option to achieve a similar width of the irrigated strip made it necessary to have the same water pressure at the reel (785 kPa) in both system options.

To evaluate the performance of the two systems it was installed in the field a line of catch cans, 3 m apart, across the towpath, in two field locations, 50 m apart, using the methodology proposed by Merriam & Keller (1978). The catch containers where chosen according to the ASAE standards (ASAE, 1995), and where put in a 1 m high support, in order to avoid crop interference.

Irrigation events were made with 3 traveling speeds (10, 30 and 40 m/h), corresponding to three different application depths, in a single pass. For each velocity and system option 2 irrigation events were done. The overlapping of two adjacent irrigated strips was simulated according to the methodology presented by Merriam & Keller (1978).

The performance indicators used were:

- *Christiansen's Coefficient of Uniformity* (CU) (Christiansen, 1942):

$$CU(\%) = \left( 1 - \frac{\sum_{i=1}^{n} \left| x_i - \bar{x} \right|}{\bar{x}\, n} \right) \times 100 \qquad (1)$$

where

$x_i$ = water depth collected by catch cans;

$\bar{x}$ = mean water depth collected in all catch cans;

n = total number of catch cans used in the evaluation.

- *Distribution Uniformity* (DU):

$$DU = \frac{\text{Average low quarter depth of water collected}}{\text{Average depth of water collected}} \times 100 \qquad (2)$$

- *Potential application efficiency (PELQ)*:

$$PELQ = \frac{\text{Average low quarter depth of water collected}}{\text{Average depth of water applied}} \times 100 \qquad (3)$$

The average depth of water applied is calculated dividing the system flow rate by the towpath spacing times the machine's traveling speed.

Evaporation and wind drift losses were determined by the difference between the average depth of water applied and the average depth of water collected in the catch cans.

## RESULTS AND DISCUSSION

***Irrigation Uniformity***

Comparing the average uniformity of all the irrigation events (Table 1) it's possible to conclude that the line of sprinklers allows a better irrigation uniformity for all traveling speeds. The results in Table 1 were obtained with wind speeds ranging from 1,4 to 4,0 m/s, which did not present significant differences ($p>0,05$) in the events with the same traveling speed for both system options.

*TABLE 1. Uniformity values for both system options in a single pass (Valeurs d'uniformité pour les deux options de système dans un passage simple).*

| Traveling speed (m/h) | Traveler with a line of sprinklers | | | | Traveler with the gun-sprinkler | | | |
|---|---|---|---|---|---|---|---|---|
| CU | *Max* | *Min* | *Avg* | *Std.dev.* | *Max* | *Min* | *Avg* | *Std.dev.* |
| 10 | 0,75 | 0,53 | 0,64 | 0,109 | 0,75 | 0,28 | 0,51 | 0,237 |
| 30 | 0,72 | 0,58 | 0,64 | 0,067 | 0,50 | 0,42 | 0,46 | 0,042 |
| 40 | 0,80 | 0,61 | 0,69 | 0,083 | 0,37 | 0,34 | 0,36 | 0,014 |
| DU | *Max* | *Min* | *Avg* | *Std.dev.* | *Max* | *Min* | *Avg* | *Std.dev.* |
| 10 | 0,60 | 0,19 | 0,37 | 0,206 | 0,53 | 0,06 | 0,28 | 0,227 |
| 30 | 0,52 | 0,27 | 0,35 | 0,114 | 0,19 | 0,13 | 0,16 | 0,028 |
| 40 | 0,71 | 0,34 | 0,46 | 0,174 | 0,14 | 0,05 | 0,10 | 0,037 |

The irrigation uniformity in the events with the line of sprinklers was very similar for all traveling speeds, but with the gun-sprinkler it decreases with the increase of traveling speed. Table 1 also shows that in a single pass the boundaries of the irrigated strip received a significant less amount of water, which leads to very low Distribution Uniformity, especially in the gun-sprinkler. Both uniformity parameters did not show significant differences ($p>0,05$) within system options for different traveling speeds, but the differences were significant ($p<0,05$) for the higher speeds between system options.

The CU values obtained are within the range of values presented in other studies. Keller & Bliesner (1990) referring to irrigations with a gun-sprinkler traveler with wind speeds near 4 m/s, reported typical CU values of only 70 to 75 % in the central portions of the field, when recommended towpath spacing was used. With a single pass less uniformity is expected, as occurred in Braz (1998) and Madeira (2000) studies. These authors presented CU and DU values similar and even lower to those in Table 1, with even lower wind speeds.

***Evaporation and wind drift losses***

The differences in the applied water depth with the two system options for each individual traveling speed were very small (Table 2) and the corresponding collected water depths did not have significant differences ($p>0,05$). So, the different evaporation and wind drift losses are mainly due to wind effect on each system water application characteristics.

Evaporation and wind drift losses are higher with the lower traveling speeds. These lead to longer application time, thus to more susceptibility to wind effect. The values presented in Table 2 have significant differences ($p<0,05$) between system options with the two lower traveling speeds (10 and 30 m/h). The gun-sprinkler is less affected by wind because the water is applied with bigger drops that can resist more to wind drift. In this option it can also be seen that some irrigation events had more collected than applied water, which leads to a negative value of the evaporation and wind drift losses. This phenomena has two possible explanations: i) the wind effect, that increases the application wetted diameter, making the catch cans receive more water than that they would receive with a normal application wetted diameter; ii) variations in the soil water content, that produce variations in the machine’s traveling speed, leading to an applied water depth different from the one determined with a regular travel speed. Higher soil water content makes more difficult the machine movement along the towpath, decreasing traveling speed and increasing the applied water depth.

*TABLE 2. Average depths of Applied and Collected water and Evaporation and Wind Drift Losses in a single pass for both system options (Hauteurs moyennes d'eau appliquées et rassemblées et pertes par évaporation et par dérive du vent dans un passage simple, pour les deux options de système ).*

| Traveling speed (m/h) | Traveler with a line of sprinklers | | | Traveler with the gun-sprinkler | | |
|---|---|---|---|---|---|---|
| | *Applied water (mm)* | *Collected water (mm)* | *Losses (%)* | *Applied water (mm)* | *Collected water (mm)* | *Losses (%)* |
| 10 | 32,4 | 17,1 | 47,2 | 29,8 | 20,2 | 32,2 |
| 30 | 10,8 | 10,1 | 6,5 | 10,1 | 10,2 | 0,0 |
| 40 | 8,1 | 7,8 | 3,7 | 7,5 | 9,3 | -24,0 |

***Potential Application Efficiency***

Although there were more evaporation and wind drift losses with the line of sprinklers, this option had higher potential application efficiency (PELQ) values for all traveling speeds comparing to the gun-sprinkler system (Table 3). The data analysis show that does not exist significant differences ($p>0,05$) in the PELQ values for all the traveling speeds within each system option. Between systems, the differences are significant ($p<0,05$) only for the higher traveling speed (40 m/h). The PELQ values are low in most irrigation events also due to the low uniformity of the irrigations.

*TABLE 3. Potential Application Efficiency (PELQ) values for both system options in a single pass (Valeurs de l'efficience potentielle d'application (PELQ) pour les deux options de système, dans un passage simple).*

| Travelingspeed (m/h) | Traveler with a line of sprinklers | | | | Traveler with the gun-sprinkler | | | |
|---|---|---|---|---|---|---|---|---|
| | *Max* | *Min* | *Avg* | *Std.dev.* | *Max* | *Min* | *Avg* | *Std.dev.* |
| 10 | 0,47 | 0,08 | 0,22 | 0,177 | 0,36 | 0,03 | 0,20 | 0,162 |
| 30 | 0,53 | 0,18 | 0,34 | 0,147 | 0,23 | 0,11 | 0,17 | 0,050 |
| 40 | 0,71 | 0,27 | 0,44 | 0,189 | 0,18 | 0,05 | 0,12 | 0,054 |

***Wind effect***

Wind is one, if not the major factor affecting the water application uniformity in sprinkler irrigation. Not only variations in wind speed but also in wind direction can drift water across the field decreasing the irrigation uniformity. Different droplet sizes, applied water depths and sprinkler application characteristics (jet trajectory, rotating speed, etc) can be more or less affected by wind. Figures 2 and 3 can show the wind effect in CU and PELQ for two different traveling speeds (10 and 30 m/h) for both system options.

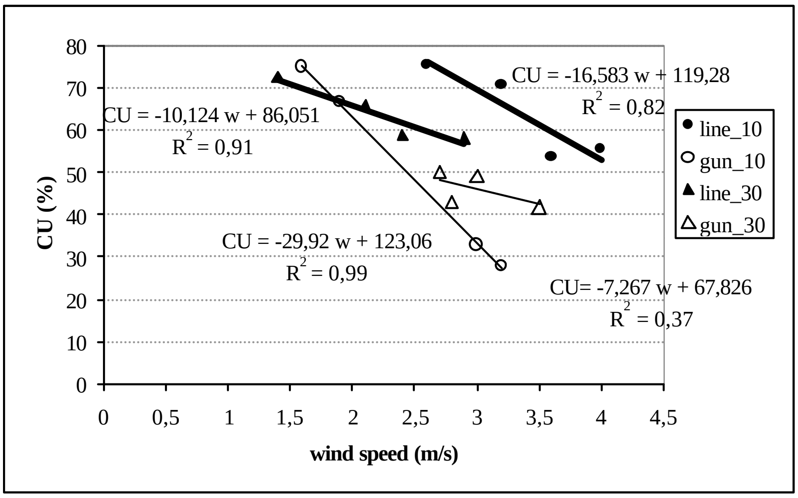


*Figure 2.Variation of CU with wind speed for both irrigation system options with two traveling speeds: 10 and 30 m/h (Variation de CU avec la vitesse de vent pour les deux options de système d'irrigation avec deux vitesses de déplacement: 10 et 30 m/h).*

The wind effect on CU is notorious and it's possible to see that with the increase in wind speed CU decreases. In both traveling speeds, for the same wind speed the line of sprinklers has always a higher CU value, which allows to conclude that the wind speed has less effect in the irrigation uniformity with this system option. It's also possible to observe that with the lower traveling speed (10 m/h) the increase in wind speed leads to a higher decrease in CU for the gun-sprinkler than for the line of sprinklers.

Figure 3 shows that with the line of sprinklers it is also possible to obtain higher PELQ values for the same wind speed in both traveling speeds when comparing to the gun-sprinkler.

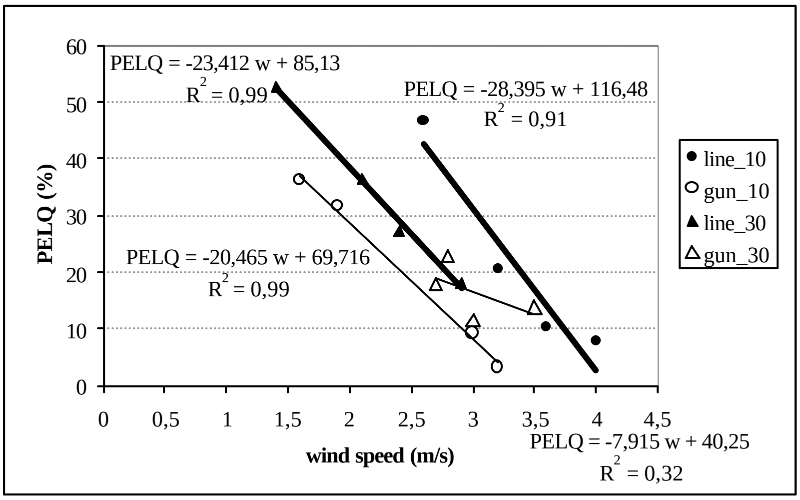


*Figure 3. Variation of PELQ with wind speed for both irrigation system options with two traveling speeds: 10 and 30 m/h (Variation de PELQ avec la vitesse du vent pour les deux options de système d'irrigation avec deux vitesses de déplacement: 10 et 30 m/h ).*

***Overlapping irrigated strips***

The overlap of adjacent irrigated strips can be a solution for increasing the irrigation performance. Both system options show an increase in uniformity and efficiency with overlapping (Figures 4 and 5).

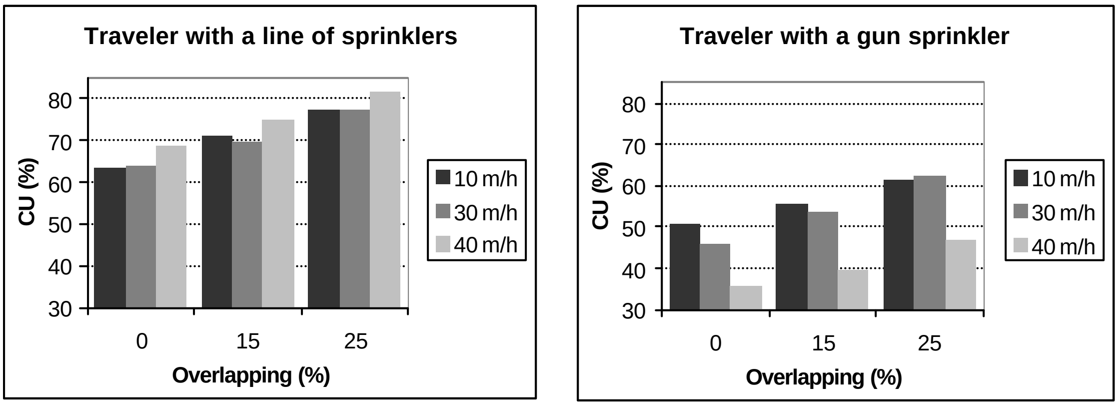


*Figure 4. Average CU values for both system options and different traveling speeds and overlapping percentages (Valeurs moyennes de CU pour les deux options de système a différentes vitesses et pourcentages de recouvrement).*

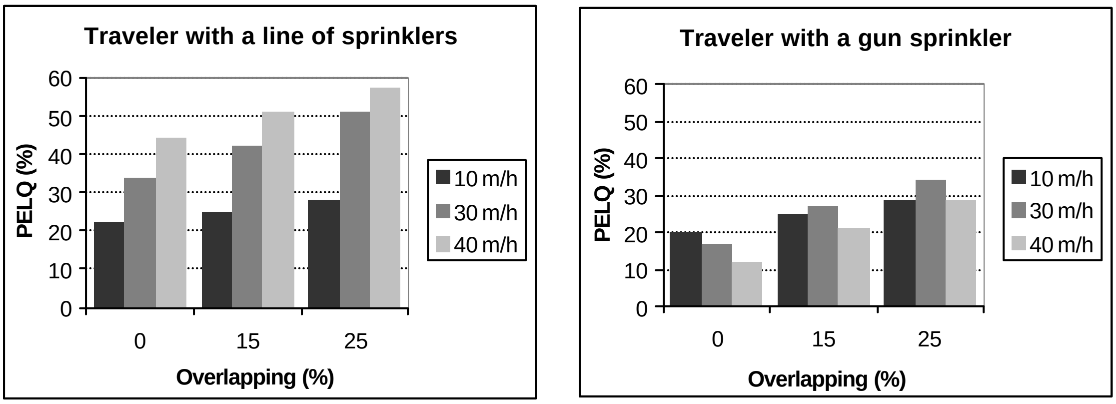


*Figure 5. Average PELQ values for both system options and different traveling speeds and overlapping percentages (Valeurs moyennes de PELQ pour les deux options de système et différentes vitesses et pourcentages de recouvrement).*

As the overlapping percentage increases, so does the irrigation performance, with similar values for both system options. With a 15 % overlapping the average increase in CU is 6 and 5 %, and in PELQ is 6 and 9 %, respectively for the line of sprinklers and gun-sprinkler. A 25 % overlapping can represent an average increase in CU of 13 % for both system options and in PELQ of 12 and 14 %, respectively for the line of sprinklers and gun-sprinkler.

## CONCLUSIONS

The results obtained in this study indicate that, with wind speeds from 1,4 to 4,0 m/s, the traveler with a line of sprinklers can allow identical water application depths with higher uniformity in all irrigated area and in the lower quarter irrigated area.

The medium pressure sprinklers apply water with smaller drops, which increase the evaporation and wind drift losses but their overlapping can produce a more uniform irrigation event allowing higher potential application efficiency.

The disadvantages of this option can be the need for more labor on moving the system to adjacent strips, since it has a heavier structure; also it's height from the soil can be a limiting factor for use with tall crops.

In both options a 25 % overlapping of adjacent strips can produce an average increase in the irrigation performance (uniformity and efficiency) of 12 to 14 %.

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