A METHOD DESCRIBING PRECISE WATER APPLICATION INTENSITY UNDER A CPIS FROM A LIMITED NUMBER OF MEASUREMENTS

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ABSTRACT

Centre pivot irrigation systems are known for their irrigation distribution performance potential. Unfortunately the performance analysis of centre pivot irrigation systems is often restricted to the uniformity of distribution. Depending on the characteristics of the applied rainfall, a system designed for high uniformity does not guarantee a high application efficiency once the system is in operation.

A method is proposed in the present paper to analyse the average rainfall depth of application and kinetic energy delivered to the soil by individual droplets all over the machine.

The method requires water distribution profiles, the distribution of droplet size and velocity along the radius of coverage for any nozzle, and pressure and height of the emitter installed on the machine. Considering the number of nozzles and the range of pressure applied, there is the need for a method calculating: the emitter maximum radius of coverage, then the rainfall distribution profile, then the droplet distribution and finally the associated kinetic energy delivery. These parameters are calculated on a new model of classical design sprayers proposed by IWT Company.

These results are being integrated on a centre pivot nozzle chart design software presented in the poster session.

INTRODUCTION

Irrigation equipment manufacturers commonly emphasize the uniformity of application to describe their systems' performance. Uniformity describes the proportion of area over/under irrigated with regard to the average application. The efficiency of the application is for the most part not considered. Efficiency is assumed here, as the ratio between the applied water that is useful to the plant and the total water applied to the plot. In this case we do not account here for the specific needs of soil leaching for example.

In general, farmers tend to apply more water than necessary to account for the various sources of system inefficiencies. The objective is to assure a minimum application depth in the least sprayed areas. As a consequence the productivity of the water obtained (in kg m^{-3}) by the agricultural systems is generally lower than the potential.

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Factors that affect the uniformity of application and, therefore, system efficiency include:

- Rainfall rate exceeding the surface storage capacity and the soil's infiltration rate. Such problems are frequently observed under centre pivot distal end and usually increase as the irrigation season progresses;
- Modification of the soil's surface by the impacting water droplets , which can gradually cause soil surface sealing and increased runoff;
- The drift of small drops under the influence of the wind.

Detrimental effects of irrigation inefficiency and non-uniformity increase when fertigation or chemigation are practised.

The designers of centre pivots tend to dimension their distribution capacity to avoid any risk of local water deficit. A moderate excess of water is generally well accepted compared to default which rapidly generates visible crop reactions and associated yield reductions.
In the case of centre pivots, the continuous variation of the water application rate along the boom makes their control more complicated than on fixed installations.

Consequently to improve centre pivots application efficiency, we have to adapt the water application characteristics to soil intake capacity, to climate conditions and to the possible sensibility of plants or the seed beds. To answer this concern we have to know:

- the amount of applied water per unit time or average irrigation intensity, compared to soil infiltration increased by surface storage capacity, at different points along the path of the machine;
- the number, size and velocity of droplets over the wetted area;
- the sensitivity to wind drift and evaporation, according to droplet size distribution, specially the proportion of drops smaller than a given limit.

To anticipate any control of all the parameters of application, it is necessary to know precisely their distribution at any point under the machine according to the combination of nozzle and pressure. A first approach has been presented by Molle (2002) on centre pivot impact sprinklers. The present application undertakes the same principles and adapts them to KSN® sprays manufactured by IWT. Such an approach allows for the selection of optimum design parameters taking into account both soil infiltration and wind drift risks.

MATERIAL AND METHODS

We have been working with the centre pivot sprayer KSN® (.1) manufactured by IWT in Austria. Its body(a) can accommodate 43 different nozzle(b) diameters, ranging from 1.8mm to 10.3mm (numbered 9 to 52), and 5 different deflectors(c).


(b)


(a)


(c)

Figure 1. KSN® Spray

This spray is connected to a hose pipe that positions the head at 1 to 3m from the ground or crop;, the range of operating pressure is 20 in 200kPa.

Considering the wide range of possible nozzle/pressure/height combinations it is not economically feasible to measure all the combinations. Thus we have tried to describe mathematically the distribution curves of every combination, from a limited number of measures, from which others (none measured) have been interpolated. We have been working on:

- the blue deflection plate, dividing the main jet issuing the nozzle in 33 sub-jets, emitted at 7° from the horizontal, the 4 other deflection plates are currently under evaluation;
- using 5 nozzles (11, 16, 23, 34, 49);
- at 5 pressures: 40, 80, 120, 160 and 200kPa, 3 only for some combinations to analyse the effect of height. This allows to cover a range of 90 to 5400l/h (when the whole series covers 60 to 6150l/h);
- the height between nozzle and measurement points was 1m, and for some limited combinations 2 and 3m;

Three types of measurements were conducted in the laboratory: flowrate versus pressure curve, radial water distribution curve and droplet size and velocity distribution according to the distance from the emitter.

Evaluation of the flowrate versus pressure curve

Nozzle evaluations were conducted using the ISO-9261 standard; 5 samples of 5 diameters of nozzles were selected and evaluated under 5 pressures (40, 80, 120, 160 and 200kPa), successively at increasing then decreasing pressure. The test facility allows regulating pressure with a precision of ±2kPa and measuring flowrate at ±5l/hour. The pressure is measured as closely as possible from the nozzle (Figure 2), this measurement doesn't account for the deflection plate used. For each nozzle diameter we have selected the average nozzle, the characteristics of which are the closest to the average of the 5 samples of the same diameter. This nozzle is then used for all the following investigations.

Evaluation of the radial water distribution curve

The radial distribution curve was established according to a protocol derived from the ISO-15886 (2005) standard. Collectors are positioned every 30cm on the first metre, then every 15cm on the rest of the radius. Collectors are 25cm in diameter with sharp edges, 25cm in height, and white in colour. Their mass is individually weighed on a scale after every test with a precision of ±0.1g (Figure 3). Every rainfall measurement is repeated 2 to 3 times according to the distance. To obtain an average water distribution curve, the spray is attached to a vertical pipe rotated by an electric engine at a speed of 2 rph. It is placed in a surrounding case preventing projections in the measurement area. Duration of the tests was 60, 90 or 120minutes. A distribution curve was obtained by averaging from 2 to 4 spray rotations.

After each rainfall measurement, a reconstituted flow is calculated from individual measurement integrated over the surface area represented. To be validated, a test shall show a reconstitution ratio between 95 and 105%.

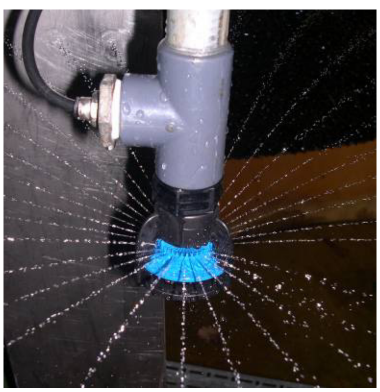


Figure 2. assembly of the Spray KSN used for the tests

Figure 3. measurement facility for average rainfall distribution tests ➔

The radial distribution of rainfall of each of 5 nozzles was measured for a height of 1m and for a pressure of 40, 80, 120, 160 and 200kPa. Nozzles 16 and 34 were also evaluated at 2 and 3m height for a pressure of 120kPa, the nozzle 23 was also evaluated at 80 and 160kPa for the same heights.

The objective is to investigate a general expression representing the rainfall distribution measured for each couple Nozzle-deflector. We have first calculated for every curve the value of the maximum radius R. According to the ISO-15886 standard, it corresponds to the point at which the rainfall collected is 0.3mm/h. This value can be interpolated linearly from the furthest two rainfall measurements recorded for every combination.

The measured values were standardized to make them comparable among each other. In this purpose every rainfall measured is converted in volume (rainfall multiplied by the surface element represented proportional to the distance from sprinkler head) divided by the total volume measured by the flow meter. The standard volumes are represented against the standard radius (r/R). This allows obtaining series of comparable curves, from which we can generalize the representation of the distribution according to every parameter of dimension and operation.

Evaluation of the droplets size and velocity distributions

This measurement is established at 7 points: 30, 40, 50, 60, 70, 80 and 90 % of the maximum radius, using a DBS (Dual Beam Spectrometer) designed by Cetp (www.cetp.fr), which is described by Delahaye and al. (2006) and marketed by Cimel-electronics (www.cimel.fr).
The DBS is constituted by two parallel IR beams of 2mm of thickness, separated by a distance of 2mm, the width is 40mm and the length 250mm. These beams are received by two photodiodes generating a tension varying according to the intensity of the light. When a particle crosses the beams, the tension decreases proportionally to the size of the particle (Figure 4). The time gap between both signals is inversely proportional to the velocity of the particle. Every particle identified is described by a date of passage, a size and a velocity. A fourth parameter indicates the quality of the detection. To limit the measurement error on the velocity, the beams are positioned perpendicular to the average trajectory of particles. To avoid any risk of projections of droplet impacting sensor's frame, the sensor is wrapped with an absorbing cover (Figure 5).

A particle of water in flight presents an elliptic section under the influence of air friction. The size of every particle is calculated from its shadow, as identified by the receiving diode, converted in equivalent diameter by using the algorithm of Pruppacher and Pitter (1971). This correction is active only for particles bigger than 1mm.

Each measurement is constituted of a minimum of 5000 particles with a range of equivalent diameter from 0.1 to 10mm.

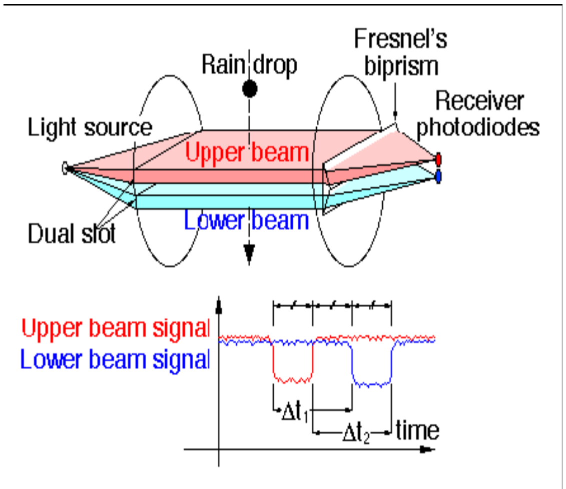


Figure 4.Operating scheme of the DBS (source Cetp)

Figure 5. DBS in measurement position, perpendicular to average droplets path, wrapped with anti-projection coating

The DBS is regularly calibrated by using calibrated steel balls crossing the beams with increasing falling velocities (ellipticity correction is neutralised). The average error varies according to the equivalent diameter of particles, between 5% for the particles less than 500µm, and 2% for particles up to 5mm of equivalent diameter. A calibration made by means of drops calibrated by needles of syringe, falling from 4m height, weighted by a precision scale compared to equivalent volume calculated from the sensor gave an error of 3% for droplets between 2.0 and 3.5mm.

This error is higher than observed with calibrated balls for two main reasons: the variability of the shape of particles, a falling velocity lower than the maximum value which is considered in the correction of Pruppacher and Pitter (1971).

For every measure we calculate the following parameters:

- Collected volume (converted in mm) and measured rainfall (mm/h): sum of volumes of the sampled droplets reported over the sampling surface area of the sensor and to the time of measurement;
- Sauter Diameter

$$D_{32} = \sum n_i d_i^3 \Big/ \sum n_i d_i^2$$

is the ratio between the cumulative droplet volumes (d_i^3)and the cumulative droplet surface (d_i^2). It gives, on the average, an indication on droplet drag, thus of their sensitivity to wind and their potential evaporation surface;

- The scatter of the distribution is evaluated by *DispN10* and *DispN25* for the distribution by numbers and *DispV10* and *DispV25* for the distributions of volumes, with:

$$DispN10 = (D_{N90} - D_{N10})/D_{N50}\ ,\ DispN25 = (D_{N75} - D_{N25})/D_{N50}\ ,$$

where D_{Nxx} is the diameter at which xx% of the number (respectively volume) is under the given limit of diameter. This parameter gives no idea of the possible asymmetry of the distribution. It doesn't make any problem for this sprayer distribution. It may not be correct for impact sprinklers for which the dispersion of droplet diameters is generally asymmetrical;
- The water application intensity, in mm/h, inside a sliding window of 60, 30, 20, 10, 5, 2 and 1seconde. This parameter helps understanding the chronology of water application and its heterogeneity during watering time. This parameter is more adapted to single jet distribution than spray type one;
- Different way of calculating kinetic energy (KE) can be used for sprinklers benchmarking:
  - total KE related to application duration (Wh),
  - averaged according to a unit surface area (W/m²) during a given time interval (60, 30, 20, 10, 5, 2, 1second),
  - integrated over the whole radius (J/kg).

RESULTS AND DISCUSSIONS

Evaluation of the flowrate versus pressure distribution curve

The measurements were conducted with increasing and decreasing pressure. This showed that there was no hysteretic effect on these nozzles, in the interval of pressures considered. For each of the 5 evaluated nozzles we tried to adjust a curve using an equation such as:

$$Q = \alpha \times P^x$$

With Q: flowrate and P: pressure measured at sprayer inlet. Results of adjustment are given in the Table 1, considering all the measurements of 5 nozzles, for each diameter.

Table 1: adjusted parameters for Q=f(P)

Nozzle	Size 11	Size 16	Size 23	Size 34	Size 49
Coefficient α	0.1702	0.403	0.8234	1.7706	3.6346
Exponent x	0.5015	0.5146	0.5179	0.521	0.519
Global R2	0.9974	0.9994	0.9987	0.9999	0.9996

This analysis using the nozzle diameter allows describing exactly the equation of every nozzle. For calculating the water distribution of a centre pivot, a general expression of flowrate delivery at each outlet is necessary. The general expression taking into account the diameter of nozzles, adjusted by the least square method, is:

$$Q = 0.040 \times D^{1.984} \times P^{0.517}$$

With a determination coefficient R2=0.998. A comparison of the values measured on the 5 diameters of nozzles and the values calculated by the model is given in Figure 6.

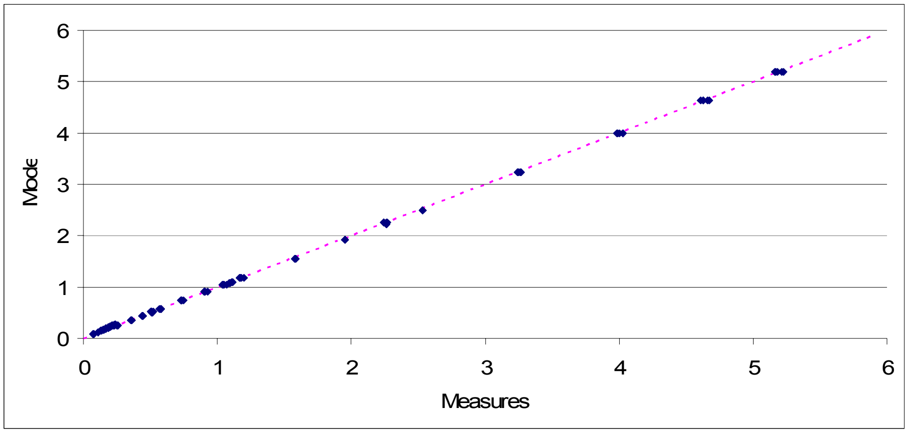


Figure 6. Comparison between measured and calculated flowrates for the 5 nozzles diameters analysed

The average error is $10^{-4} m^3/h$, and the standard deviation of the error of $2.2\ 10^{-2} m^3/h$. This error is bigger on the smallest diameters.

Evaluation of the radial water distribution curve

Figure 7 shows a sample of measurements results obtained on 9 of 33 evaluated combinations, for the 23 (4.6mm) nozzle.

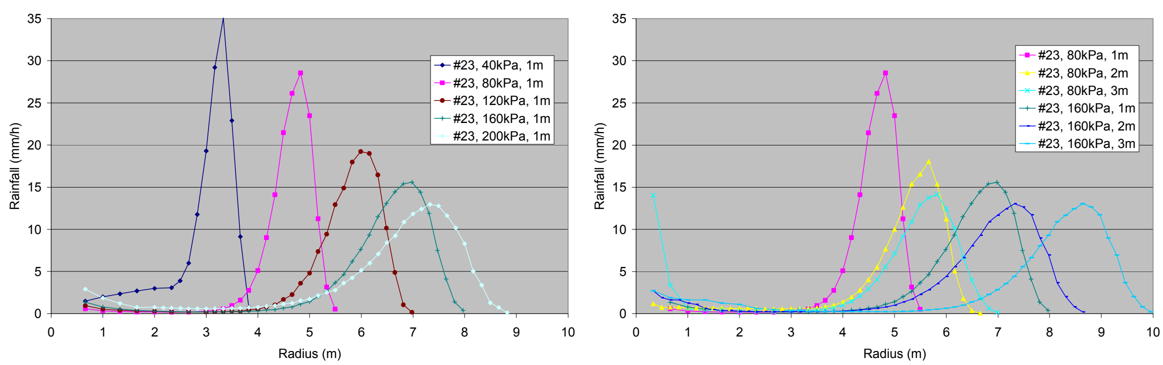


Figure 7. Nozzle 23, Effect of pressure and height on rainfall distribution

To give a general representation of the distribution curves, it is necessary to standardize data according to the radius. We calculated the maximum radius for every combination, then fitted these radii to the operating and dimension parameters of the spray. We first used the equation proposed by Kincaid (1982) for impact sprinklers: $R = \alpha\left(Q \times \sqrt{P}\right)^{\beta}$, but results were unsatisfactory. After several attempts, we selected a power function undertaking all the parameters considered for a given deflector:

$$R = a \times D^b \times P^c \times Q^d \times H^e$$

With R: radius in m, D: nozzle diameter, P: pressure in bar, Q flowrate in m^3/h and H: height above collection surface in m.

The parameters calibrated for the blue deflector are: a=43.4; b=-1.215, c=0.109; d=0.832; e=0.24 and the coefficient of determination is $R^2=0.97$.

The values measured and adjusted are shown in Figure 8:

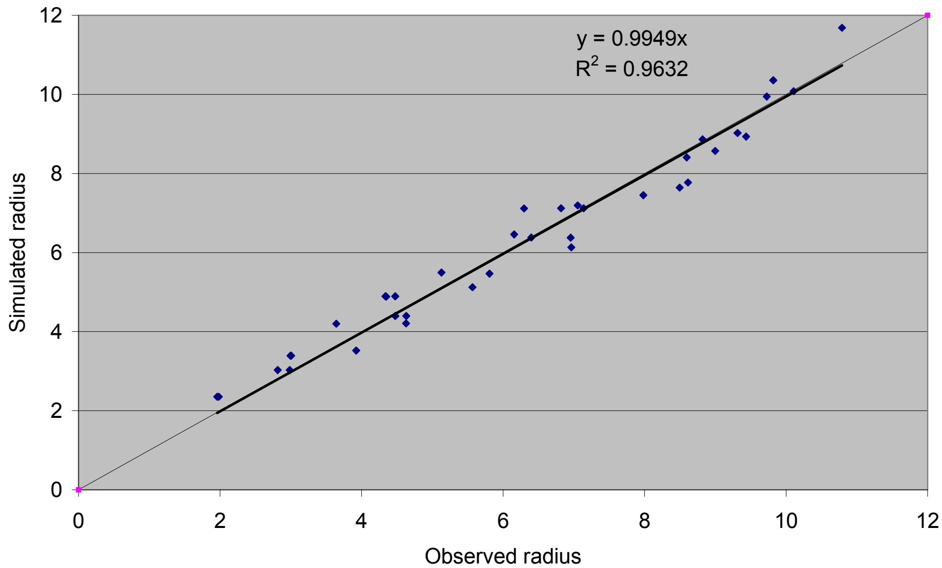


Figure 8. Comparison of measured and calculated radius

The average error calculated is: 0.014m with a standard deviation of 0.47m, the interval of variation of the error is [-0.89m ; 0.85m], corresponding to a relative deviation varying from 2% to 20%. We consider this result satisfying for our objective of calculation of the rainfall distribution curve of a centre pivot.

This type of adjustment tested on the other deflectors gave similar results. We still have to refine the proposed model which undertakes redundant parameters: the flowrate Q on one hand, the diameter D and the pressure P on the other hand.

The standardised water distribution was unsatisfactorily simulated using the standard radius, and normal distribution functions (Figure 9). As an alternative, we calculated 10 characteristic values for every distribution, the first one at 5% of the radius and the rest at increments of 10 % of the radius. From these values, the water distribution of unevaluated nozzle-pressure combinations will be calculated using interpolation.

An attempt is to be made in the future with a probabilistic method proposed by Legat, Molle (2000).

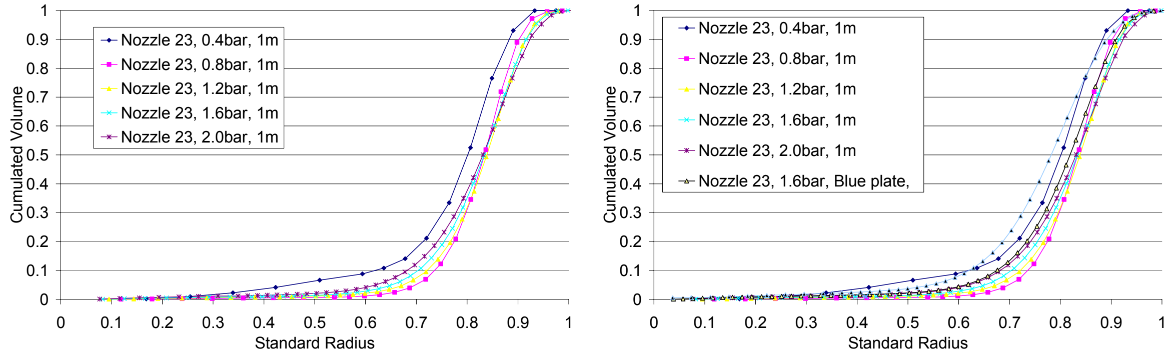
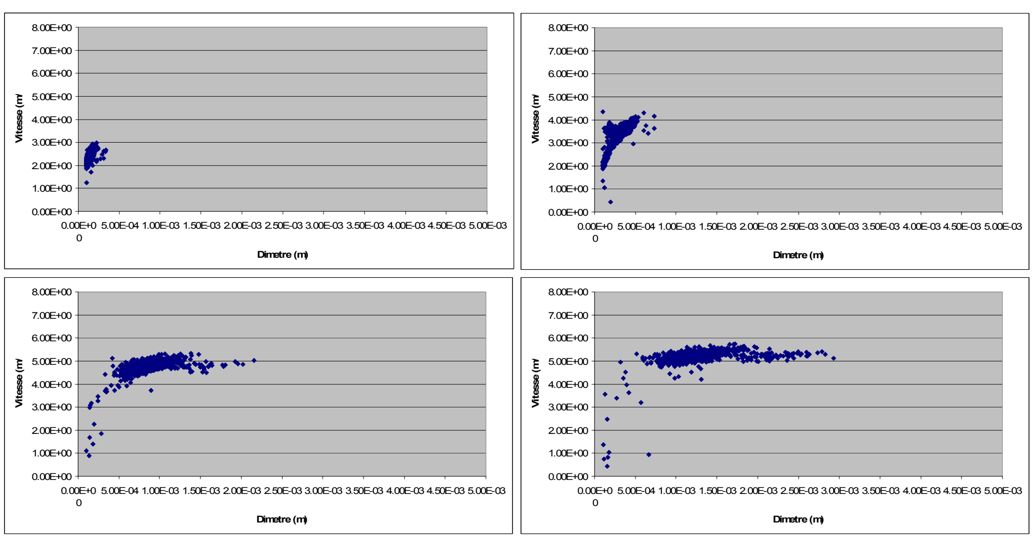


Figure 9. Example of standardised water distribution for nozzle 23 according to pressure and height

Evaluation of the droplets distribution sizes

Figure 10 shows the results of droplet sampling at 5 radial points. Note that particle sizes are growing with distance from the sprayer. This size varies from 0.1mm (limit of DBS detection) to 3mm. At the lower pressures the maximum size can exceed 5mm. The dispersion of the jet in particles is rather rapid on this type of spray, and droplets distribution parameters are varying more rapidly than what is observed with sprinkler jet type distributions. Big particles having a lower drag coefficient travel further than small ones, their velocity at impact on the soil is 6m/s on the average.



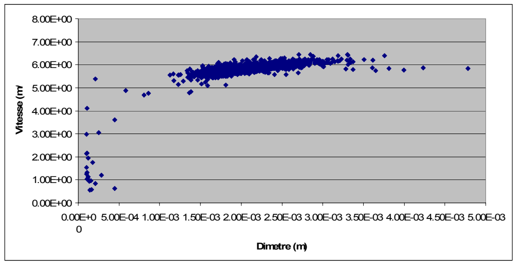


Figure 10. Nozzle 23, pressure 160kPa, height 1m, Radius : 2.66m (33%), 4.00m (50%), 5.66m (71%), 6.33m (79%), and 7.00m (88%)

The analysis of these distributions (Figure 11) shows that they are generally unimodal, except in several combinations at the far end of the radius, where some big particles eventually burst into smaller particles, as observed in the last chart of Figure 10. We can also note that distribution curves in volume are shifted to the right, with regard to distribution in numbers. In our example, beyond 4.3m (75 % of the radius), 80% of the volume of water is applied in the form of droplets bigger than 1mm. On a spray with rotor, for example we have observed a similar phenomenon but with droplets bigger that 2.5mm. The predominance of droplets bigger than 2mm decreases the sensitivity of water distribution to the wind (Hendawi and al. 2005) but increases considerably the risks of excess application intensity.

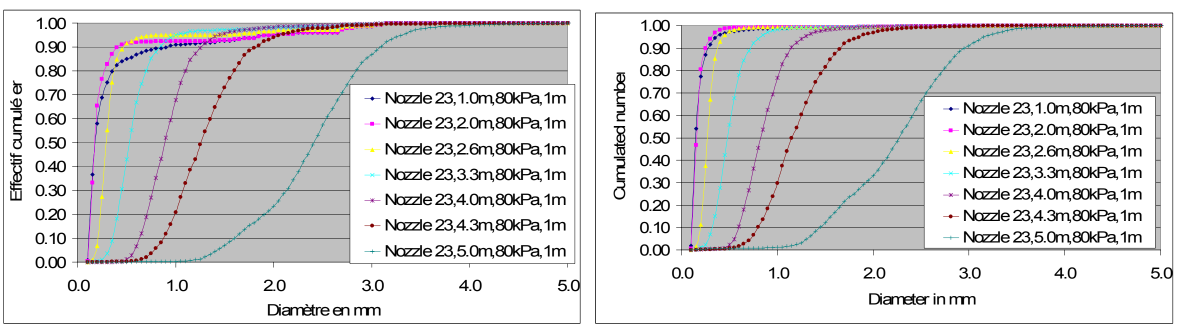


Figure 11. Cumulated Numbers and Volume per class of droplets diameters for nozzle 23 at 80kPa

To qualify the distribution of droplets diameters D_i regarding their size, the best indicator is the Sauter diameter: $D_{32} = \sum D_i^3 / \sum D_i^2$. The use of NMD or D_{N50}, and VMD or D_{V50} (Number Median Diameter, and Volume Median Diameter), simpler to calculate could also be used.

We noticed that for every nozzle diameter the distribution of D_{32}, follows a quadratic law according to standard radius as illustrated in Figure 12. The same observation is made for others nozzles. We thus tried to calibrate a general equation adjusting all the values of D_{32}, related to the standard radius, whatever is the distance from the sprinkler.
All the data measured was fitted with the equation:

$$D_{32} = a \times \Phi^b \times P^c \times R_{\%}^d ;$$

With Φ : number of nozzle diameter, P: pressure in bar, R: standard radius in %. The parameters are: a=0.168, b=0.92, c=-0.163, d=2.781, the coefficient of determination is R^2=0.93. The correlation between measured and calculated values is given in Figure 13. It is considered correct according to the accuracy required for centre pivot distribution simulation.

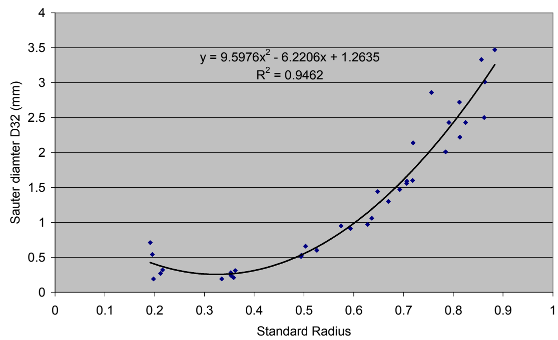


Figure 12. Sauter Diameter (D_{32}) for nozzle 34 between 40 and 200kPa, et 1m height

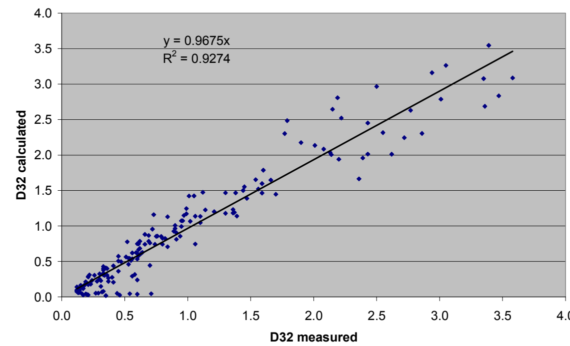


Figure 13. Correlation between Sauter diameters (D_{32}) measured and simulated for KSN spray equipped with the blue deflector, a nozzle diameter from 11 to 49, a pressure from 40 to 200kPa, and 1m height

If we observe the scattering of the distributions in Figure 14, we can notice that *DispN10* and *DispN25* don't show any trend in variation. They could be considered as constant with respective means of 0.72mm and 0.36mm. On the other hand, the values *DispV10* and *DispV25* tend to decrease with the standard radius. The presence of several big particles (not appearing in scattering in number) in the beginning of radius, can be due to rebounds or to local perturbation of the distribution by the supports attaching the deflector to the body of the sprayer.

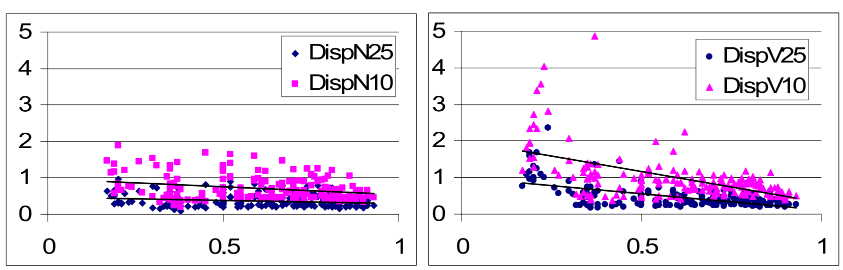


Figure 14. dispersion values of numbers and volumes for KSN spray equipped with the blue deflector, the 5 nozzles diameters from 11 to 49, 5 pressures from 40 to 200kPa, and 1m height

Evaluation of the water application intensity

The analysis of water application intensity during a limited sliding time interval shows an increase of intensity when time interval decreases. It reaches regularly and overtakes 100mm/h, for the pressures of 80 to 200kPa, with higher values up to 400mm/h for the pressure of 40kPa. The differences between the values in 60, 30 and 20secondes and the mean value are small.

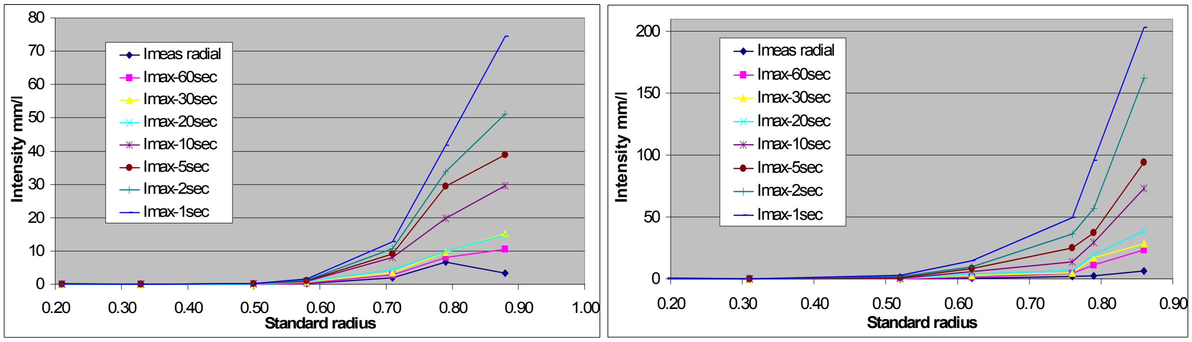


Figure 15. Nozzle 23 and nozzle 49, 160kPa, 1m, variation of maximum water application intensity related to reference time

For the biggest nozzle, which tends to saturate the deflector, these values overtake a 150mm/h for an interval smaller than 5seconds whatever is the pressure. Such intensities, even if they last shortly, can generate rearrangements of soil surface particles and initiate local saturation and runoff phenomena often observed in centre pivots distal end. Nevertheless the detrimental effect of such intensities will rely on particle number and size, not accounted in intensity analysis. That is the reason why the analysis of intensity alone is not enough, if no information is given on the kinetic energy of droplets when impacting the soil surface.

Evaluation of the Kinetic Energy (KE) distribution according to time (Wh)

As for the water application intensity approach, we tried to identify the homogeneity of the application according to time. Thus we have calculated the values of Ec (Wh/m ^{2}) during a sliding time interval of 60, 30, 20, 10, 5, 2 and 1 second. We can note that the values calculated for a window of 20 to 60secondes are equivalent. It is the same for a window of 1 to 5secondes (Figure 16). It means that the minimum time scale of KE observation for this spray must be close to 5secondes. In other words, during the passage of a jet issuing the spray, we can consider that the maximum intensity periods last less than 5secondes. This period is far over of what is observed under sprinkler jets, where maximum intensity period are concentrated on shorter period (less than 2 seconds) with higher resulting KE.

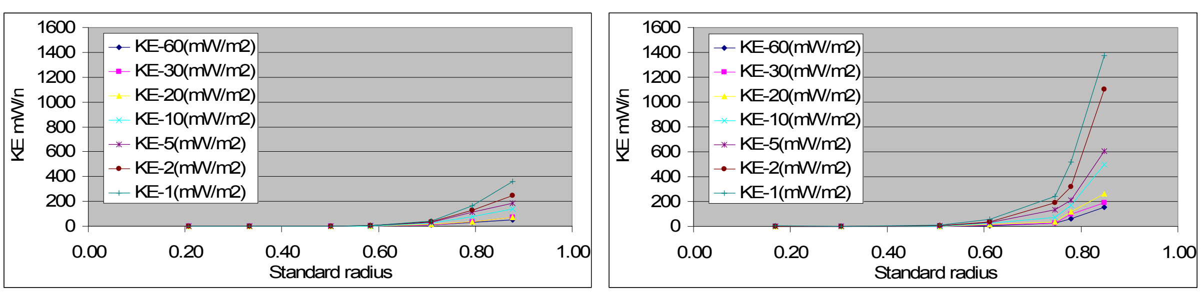


Figure 16. Nozzle 23 and nozzle 49, 160kPa, 1m, variation of Kinetic Energy of water application related to reference time

More generally Figure 17 shows that the maximum KE tends to decrease when the pressure increases between 40 and 80kPa for all the nozzles, then it remains more or less constant for the other pressures. In absolute value the pick KE increases strongly with nozzle diameter.

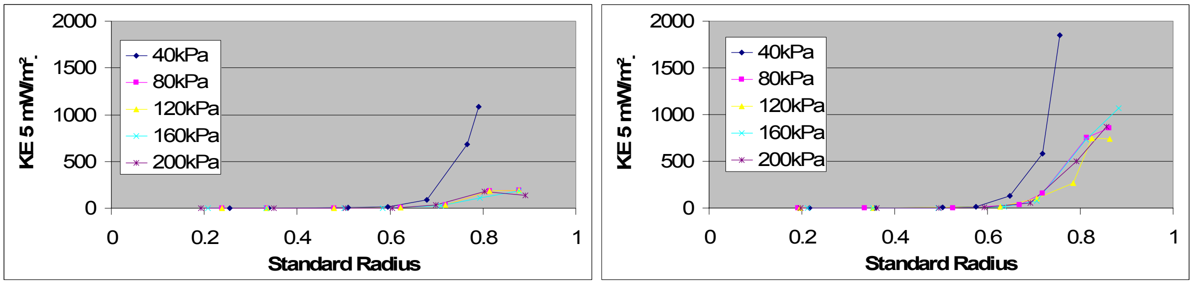


Figure 17. Nozzle 23 and nozzle 34, effect of pressure on maximum KE observed during a 5 second period

From these first results we can draw some conclusions:

- The effect of the high flowrate is less important on droplets KE when reaching the soil than the effect of pressure. These pressures should be avoided while the crop is not covering the soil, in case of fragile soils or seed beds;
- The KE of the water distribution is concentrated on approximately 30% of the radius (60 to 90%), below 70% of the radius the contribution is coming from very small particles which leave progressively the main jet or which result from the explosion of bigger particles;
- Beyond 90 % of the radius the number of particles obtained is so reduced that it is complicated to conclude.

Evaluation of the Kinetic Energy (KE) distribution in J/kg according to radius

The previous analysis shows us how KE is varying when a unit time interval is considered, but we lack the understanding of total KE delivered, disregarding the time duration of application, but according to the volume of water applied. This kind of parameter makes it possible to compare the different types of emitters between each others.
Hereafter is represented the total KE according to standard radius, nozzle size and pressure for a 1m height, measurements have been adjusted using a power function:

$$KE_{J/kg} = a \times \Phi^{b} \times P^{c} \times R_{\%}^{d}$$

With Φ : number of nozzle diameter, P: pressure in bar, R: standard radius in %. The parameters are: a=3.213, b=0.531, c=0.132, d=1.245, the coefficient of determination is R^2=0.82.

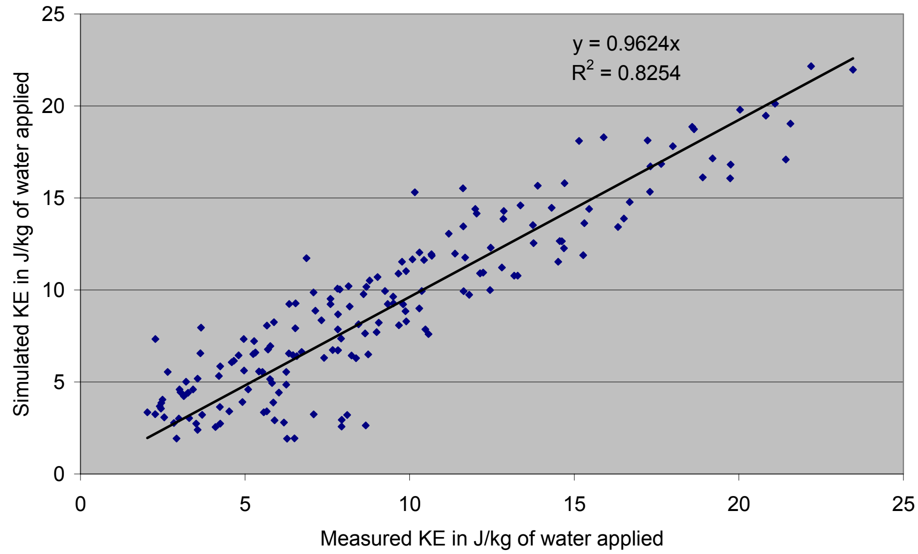


Figure 18. Comparison of KE according to nozzle size, pressure and radius in J/Kg measured and simulated

A number of points are showing high measured values compared to what could be expected. These values which have been measured at different distances, pressures and diameters, don't show any trend. They are probably due to some uncontrolled problems such as: small possible manufacturing default in the deflector, possible rebounds on the sensor frame, or too low number of droplets recorded. These issues will be analysed to improve the measurement protocol.

Evaluation of the overall total Kinetic Energy (KE) J/kg

This value appears to be the best approach to benchmark the overall KE delivered to the soil by a given sprinkler or sprayer type. The values calculated from our measurements are given in Figure 19.

The following remarks can be done:
- Nozzles 11 to 34 exhibit a more or less constant cumulative KE in the range 80 to 200kPa. The increase in maximum radius is compensating the increase in average droplets size. Consequently the operating pressure can be chosen as required from flowrate consideration, yet the cumulated KE will stay constant;
- nozzles 11 and 16 are delivering water with cumulated KE that remain low;
- nozzles 49 has a very different behaviour as cumulative KE increases with pressure. As mentioned before with such a big nozzle the plate is saturated, water is overflowing compared to the potential velocity of water issuing the plate.

It seems that for this type of sprayer, if designed over a maximum flowrate, the distribution characteristics become very bad in terms of KE.

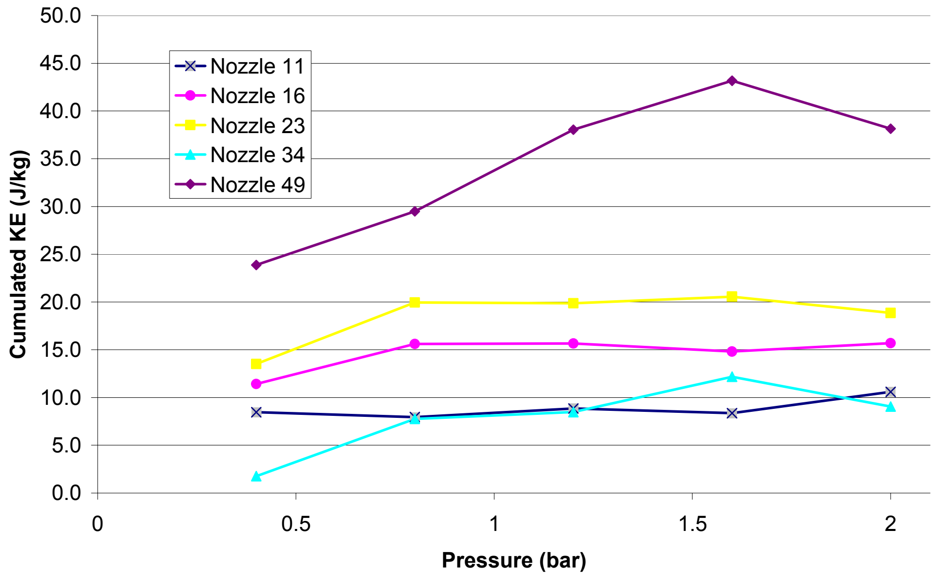


Figure 19. Cumulated KE in J/Kg for the different combinations of KSN

Some comparative values can be found in the literature. For example, with a nozzle 24/128 (equivalent to the #23 of KSN) from Kincaid (1993):

- Nelson Rotator D4, #4.8mm, 1.4bar, KE=24.3 J/Kg;
- Nelson Rotator D4, #4.8mm, 2.1bar, KE=21.3 J/Kg
- Nelson Rotator D6, #4.8mm, 1.4bar, KE=19.3 J/Kg;
- Nelson Rotator D4, #4.8mm, 2.1bar, KE=13.8 J/Kg
- Nelson Spinner D6, #4.8mm, 1.4bar, KE=14.0 J/Kg;
- Nelson Spinner D6, #4.8mm, 2.1bar, KE=11.8 J/Kg
- Nelson Spray I, Flat Plate, #4.8mm, 0.7Psi, 9.0 J/Kg
- Nelson Spray I, Flat Plate, #4.8mm, 2.1Psi, 7.7 J/Kg

A simulated rainfall of 30mm/h delivers 13 J/kg, with droplets of ND50 of 1.4mm (Leguedois, 2003)

CONCLUSIONS AND PERSPECTIVES

Measurements presented here, show that the range of operating and dimensional characteristics, that can influence water distribution parameters is wide for the blue deflection plate. The analytical method allows a consistent representation of these characteristics, compared to the precision required by the calculation of water distribution of a center pivot.

It remains to widen this method to others deflectors (Figure 1) than the blue one used here, to anticipate its generalization.

The method can be used either to qualify emitters in term of distribution characteristics, or to adapt these characteristics to the mechanical capacities of the soil to accept them.
Such characteristics are generally not known by manufacturers, there are sometimes estimated by farmers when they observe the behavior of their soils, especially when pressure is too low.

This analysis of sprayers operation, compared to standard sprinklers, shows that despite sprayers can deliver high average intensities, the overall KE delivered to soil is acceptable by numerous types of soils. This is due to the fact that water is applied in the form of small particles with low cumulated kinetic energy.

We still have to work on the mathematical description of the water distribution of the water. In particular by using the probabilistic method developed by Legat and Molle (2000). This method was based on the principle that a radial water distribution curve is in fact a combination of probability functions describing different populations of droplets diameter distributions according to the distance from the emitter.

The same results can also be used to qualify the sensitivity of distribution to losses by drift and evaporation.

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