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CEMIB: an innovative bench for spreader eco-design

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Abstract

This paper presents the CEMIB device developed by the Cemagref as a global tool to boost innovations, as well for spreader developments as for fertilisers one. The new bench method is shortly described and the advantages regarding the traditional EN13739 standard method are highlighted. Technical advantages to use the 3D spread pattern knowledge the CEMIB provides are illustrated regarding different real problems, gradually complex, for which manufacturer are commonly faced as soon as they need to improve or develop new spreader technologies or new fertiliser formulations. Then, the greater part of the paper is organised to explain some computed tools which have been developed by the Cemagref to value the most as possible information enclosed in the 3D spread pattern. The CEMIB global offer is really well positioned in the eco-design context: (i) practically, testing facilities required are around 10 times less expensive than transverse classical ones, (ii) it allows time and fertilisers saving during innovated phases of fertiliser and spreader developments, i.e. real tests can be replaced by computing simulations, and (iii) it allows analyses which should not be possible, in any case, using only the transverse spread pattern.

Keywords

Bench, Centrifugal spreading, Fertiliser, Optimisation

1. Introduction

Most of the time in Europe, mineral fertiliser application is an agricultural operation carried out using centrifugal spreaders. Relatively small, simple, and of low cost, they are also attractive because of their capacity to reach high spreading efficiency (important working widths, high tractor speed ...). Nevertheless, the spreading application uniformity is strongly dependant to numerous variable, for example the settings chosen on the spreader, or the physical fertiliser properties. Relatively complex to modelize, knowledge about the global comportment of the fertiliser granules during the spreading process, i.e. from the hopper to the ground, passing through the vanes acceleration, are not so important and precise. In any case they are not sufficient today to design, optimise, and draw out setting tables. That's the main reason why test benches are very often used. Numerous methods using collection tray are available throughout the world and are described in different standards. A lot of them use a row of collection trays aligned perpendicularly to the displacement axis of the spreader. It's in particular the case of the European standard EN 13739. The way this test is performed induces an important practical drawback nowadays, because of the reached spreading performances. For the most powerful couples spreaders / fertilisers, the spread covered area on the ground is around 85m*50m, inducing test facility dimensions around 90m*60m, considering the longitudinal needed displacement to perform the tests. Such test benches are too expensive, as well for the building or to maintain them.

Mainly performed to establish setting tables, the final goal of these tests is to obtain the variation coefficient (CV) curve from which the best working widths can be extracted: after the different spreading runs, all of the global collected quantities are weighed, allowing establishing the transverse distribution curve; this last one is after used to compute the needed transverse overlapped distributions, and the linked CV values. Several tests are also necessary to correctly work out setting tables because the method generates results hard to extrapolate: the transverse curve integrates the tractor displacement, and isn't representative of the real physical ground distribution of fertiliser granules. Computed predictions under setting variations are also impossible to develop.

A new test bench device, the CEMIB, as been drowned by the Cemagref and is used from 2006. Of a considerable practical interest, it also provides results from which many calculations can be done, simplifying the design of the spreaders, and also setting tables working out.

After a short presentation of the CEMIB device and the results it allows to obtain, technical advantages of the 3D distribution knowledge are explained. Then, practical computer tools developed by the Cemagref are described, of particular interest to provide new (eco) conception methods, or increase setting table robustness.

2. CEMIB: method description and provided results

As two main drawbacks were identify when using the traditional EN13739 standard method, i.e. practical limitation due to the needed test hall size, and technical limitation due to the integrative result it provides, the challenge was to propose a new method which should solve these two particular points.

One of the best devices to map a spread pattern should be to place a ground of sensor every where in the spread covered area! As it is evident this way should be technically, practically and economically unrealistic, a sample method becomes obligatory.

A first way to sample the spread pattern is the one described for example in the EN13739 standard: the row of collection tray is lined perpendicularly to the travel axis of the spreader. Even if it is possible to obtain the 3D spread pattern by this way, using continuous measurements of all the weighing sensors and of a specific other one for the longitudinal position, this method presents practical limitations, described in the first paragraph.

A second way consists in a radial measurement principle: the spread pattern is sampled angular sectors after angular sectors, but in a continuous way. It's this device which has been adopted and patented by the Cemagref; the name chosen is CEMIB (short for CEmagref MIneral Bench).

A fixed line of trays, equipped with sensors, represents the "sensible" part of the device, which will sample the spread pattern. At one of the extremity of these row of trays is placed the spreader to test, coupled to a rotary carrier. The angular velocity of this one can be set between $0,5$ and $8^{\circ}\cdot s^{-1}$, depending to the flow rate. During the test, thanks to the carrier, the spreader revolves around itself around an axis not far from the disc axis (Fig. 1), in such a way that each point of the spread pattern passes the collection trays vertically at a certain point (Fig. 2).



Fig. 1: CEMIB device photograph, with a real spreader coupled for testing.

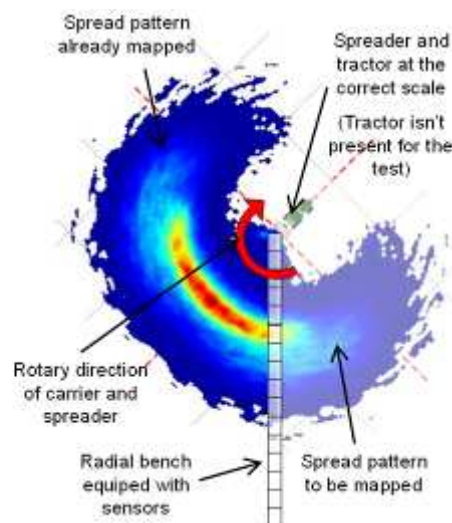


Fig. 2: General principle of operation.

The 3D spread pattern obtained (Fig. 2) is a fertiliser density matrix on the ground, obtained after mathematic calculations, in particular a spatial interpolation which allows going from densities expressed as polar coordinates to densities expressed as Cartesian one. From this fertiliser spread pattern, the transverse distribution, explained in the EN13739 standard, can be obtained using a summation column by column (Fig. 3). All the following calculation described by the standard can also be computed (overlapped curve, CV curve, global rate applied ...), as well for main field applications as for border applications.

In a very small test hall facility (40m*10m are enough), this device allows assessing the same results as the one obtained using the standard method, and in addition, the 3D spread pattern is measured, on which many interesting calculation can be work out (see paragraph 3).

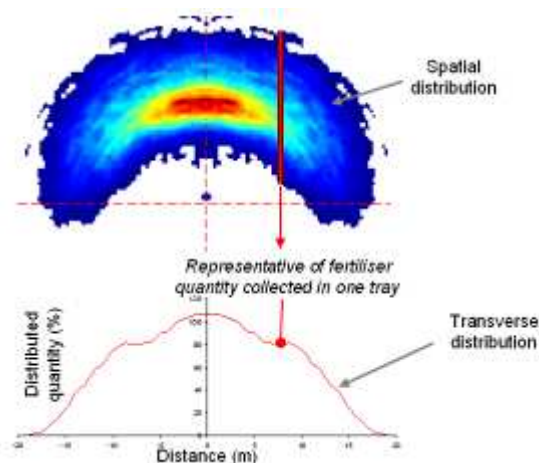


Fig. 3: Transverse distribution obtaining from spatial distribution.

From 2005 when it was developed and presented (Piron, and Miclet, 2005), many complementary comparative and round-robin tests have been carried out between different test facilities in Europe, using EN13739 standard. All the results show a global valid correlation between both methods. In addition, some experimental and scientific works have been carried out in order to prove the validity of this evaluation device in any using case. On an economical point of view, such a solution presents a very important upside because the total costs induced to build the test facility is around 10 times less important than for a transverse test bench as described in the EN13739. Always in opposition to the transverse bench, running costs are very low, because of the test hall area and volume difference (between 10 and 15 times less important) and all the linked costs as air conditioning and heating, time to clean ...

3. Technical advantages to use 3D spread pattern

The different spreader factories used many different way to set there spreader. Variation of horizontal vanes inclinations on the disc or of there length, variation of the global spreader horizontality in both axis longitudinal or transversal, variation of the fertiliser drop zone position, of the disc angular velocity, ... More and more, with great working widths, a correct homogeneity distribution is obtained using 2 or 3 different of these settings on the same spreader, then it becomes very hard to go fast to the correct choice. The 3D spread pattern knowledge is in these cases of great interest, and the strongest results are obtained using the 3D spread pattern measured from only one disc. The values obtained do enable phenomena to be explained or assessed, and therefore it is possible to predict some reactions, to modelize ...

3.1. Test comparison one disc spread pattern vs both disc spread pattern

Using a spreader equipped with 2 equivalent discs, the right disc (RD) and the left one (LD), 3 successive tests are carried out with identical settings and the same fertiliser. The feeding of the discs is different for each test: RD feeding only, then LD feeding only, and finally both discs feeding together (RD+LD).

Both spread pattern RD and LD are expressed in their respective disc axis repair while the RD+LD spread pattern is expressed in the spreader repair, i.e. the X value "0" is in this case at the middle of the 2 discs. RD and LD spread pattern are added together after repair changing, and the result is compared to RD+LD spread pattern. This comparison is showed on the Fig. 4. It can be seen that, except differences due to experimental errors, the results are the same, as well for the transverse curve, as for the CV one. As soon as the goals of the tests is the spreading process comprehension, or specific spreading pieces design, or setting tables work out, the best way is to measure with only one disc. Since the spreading process is isolated, extrapolations aren't by this way necessary.

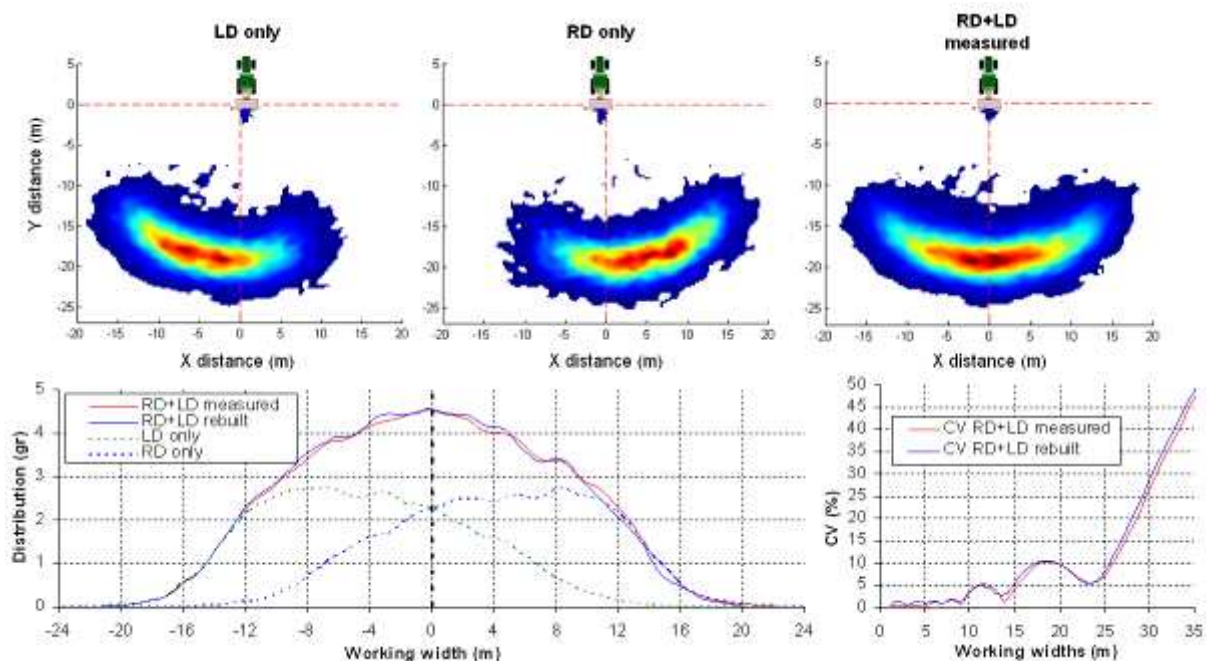


Fig. 4: Comparison of results obtained measuring spread pattern of each disc separately then add them together, with the spread pattern obtained using both discs simultaneously.

3.2. Tools developed to increase spreading development efficiency

Regarding the setting to be used, predictions of results are more or less easy to obtain. For many of them, physical models are required in addition to the 3D distribution in order to predict the distribution using another setting. That's the case for example for the spreader inclination. Horizontality angle of the vane on the disc required to go upper in the understanding of the work of each vane before to be able to predict anything. Anyway, it's possible using more or less elaborate strategies to reach the objectives.

Two settings are more directly useful for spreading predictions: the angular variation of fertiliser drop zone on the disc, or the variation of the disc angular velocity.

For the first one, the fertiliser is dropped with more or less the same deposition shape on the disc, but with different possible angular positions around the centre of the disc, in regard with the spreader travel axis. For each possible setting index, the way the fertiliser granules are accelerated by the vanes is then exactly the same (i.e. the acceleration time, the relative mass angular distribution, the absolute granules velocities ...). The only spreading

consequence induced is the absolute angular rotation of the spread pattern according to the absolute drop zone angle.

The knowledge of the mechanical building characteristics of a spreader allows in this case reducing a lot the number of real bench tests to reach a working width objective, using initially only 1 real measurement (Fig. 5). In this example, a first test (Initial test (a)) shows a setting index with which the working width is too large regarding the wanted objective: optimum working width can be seen equal to 30m, with a 10% CV value. Taking this test result in the computer simulator, 7,5° of rotation angle is found to be optimum to work at 24m (part (b) on the Fig. 5). The fertiliser density difference (b)-(a) shows this 7,5° global rotation (red and yellow points mean densities higher than 0, and blue points correspond to densities lower than 0). After modifying the spreader setting according to this objective of rotation, the second test is performed (c). A first comparison between prediction and reality is obtained computing the fertiliser density difference (c)-(b): the red, yellow and blue points are regularly laid-out everywhere which means a global equivalence of both 3D distributions. The second comparison is obtained regarding the matched correspondence between transverse simulated curves and real measured one. The CV calculations confirm this equivalence since both curves are exactly the same, in particular with an identical CV value of 2% for the best 24m working width.

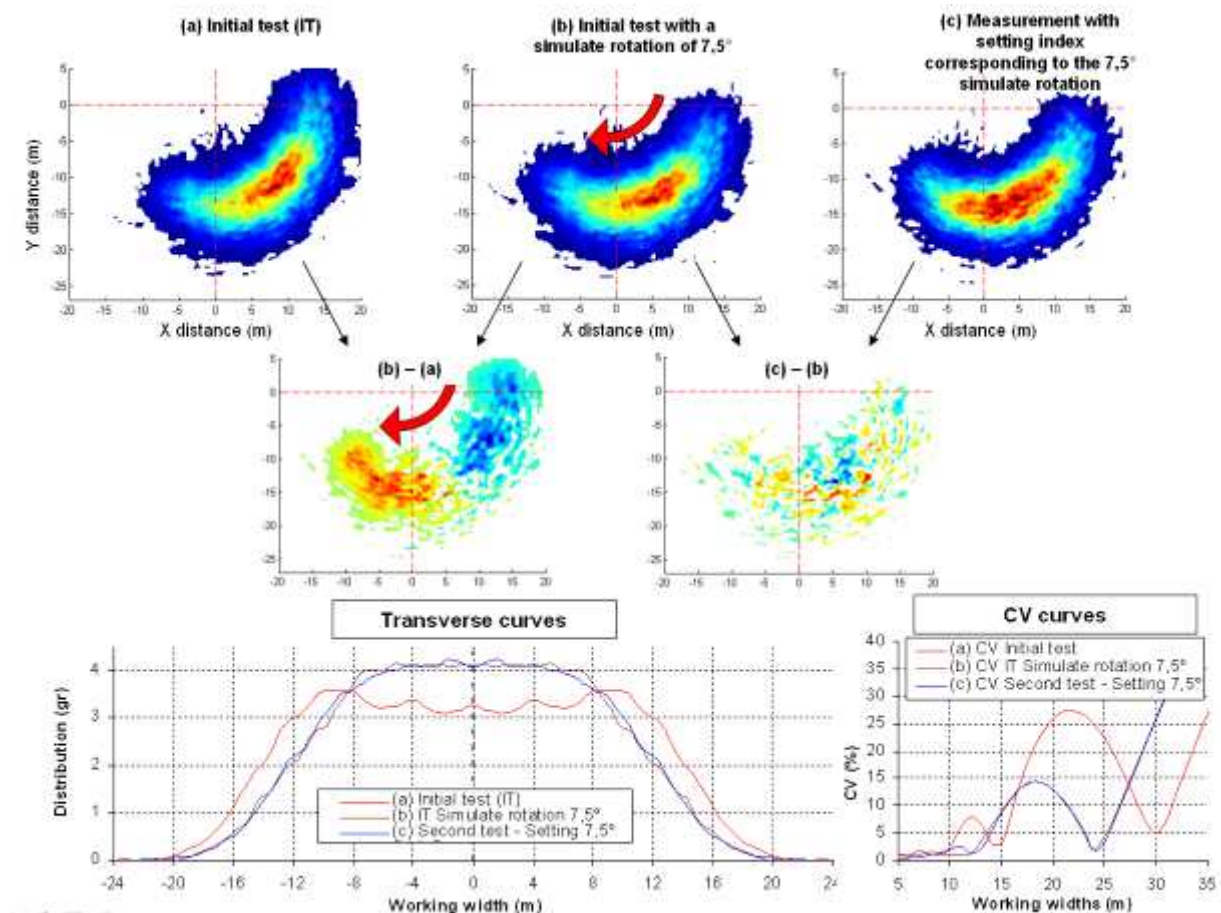


Fig. 5: Presentation of the working progress of the comparison tool.

The developed tool allows selecting one or two different 3D distributions for each spread pattern to compare, in order to associate them together with more or less rotation shifts, flow rates, fertiliser angular velocities ..., and decide the way to follow for vane or disc design ...

Identical ways of simulation are available on the tool developed, in particular to predict the results using different disc angular velocities. The other spreader settings consequences and there implementation to predict results are in development.

3.3. Tools developed to automate setting table establishment

This computer simulation way has been completed to assess an automatic research of the best settings for one fertiliser, spread with a specific spreader, on all the realistic working widths, and using only one test (Fig. 6).

Using a spread pattern measured and different parameters as the setting index chosen for the test, the mechanical characteristics of the spreader, an experimental law giving the projection distance in relation with the disc angular velocity ..., the developed computer tool calculates all the possible spread patterns which can be obtained with the available spreader settings (Fig. 6-a). It can also compute each corresponding transverse distributions (Fig. 6-b) and their associated CV curves (Fig. 6-c). These last ones are stored in a CV matrix results (Fig. 6-d), where spreader settings (Y axis) can be crossed with the working widths (X axis) to find all the predicted CV values (Z axis).

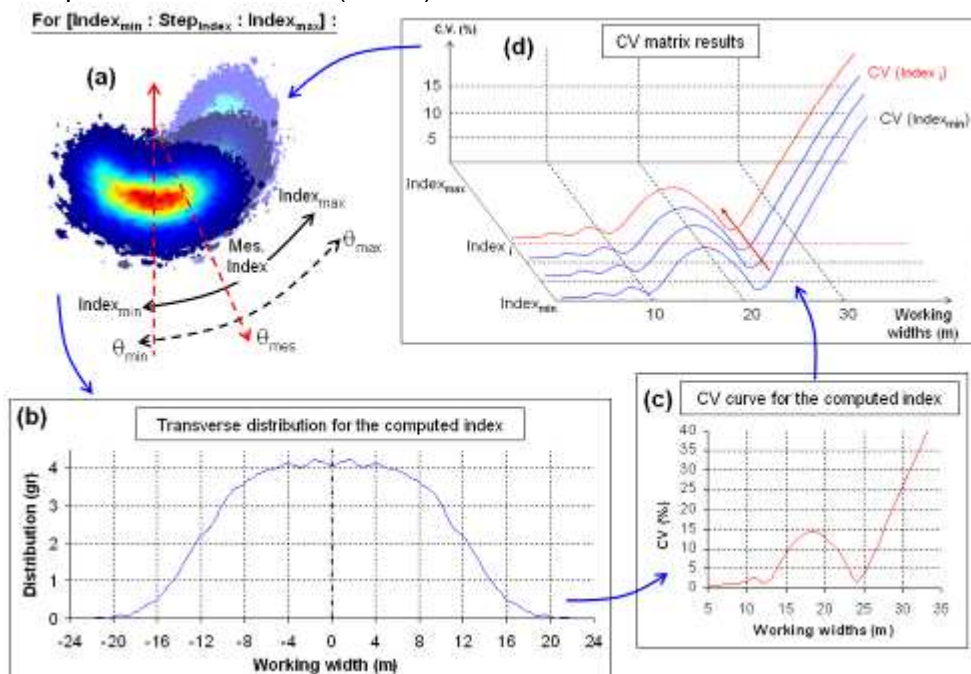


Fig. 6: Illustration of the computed progress used by the optimization tool to predict as well as possible spreading homogeneities, i.e. CV values, regarding all the available settings, and a range of possible working widths, using only one real spreading measurement.

This computing process produces the results shown on Fig. 7. CV matrix results are presented on the colored 3D graph where the colours represent the different range of CV, from [0 – 5%] to [> 30%]. For each working width between 2 and 50m, the setting allowing the best CV result is searched, and materializes on the graph by a white point. All the obtained points draw the white trajectory (c) which can be considered as the best range of settings to choose for the spreading of the given fertiliser with this spreader general configuration (i.e. type of disc ...).

This pool of "best settings" is reported on a 2D graph (b) which directly show the setting to choose (Y axis) regarding the wanted working width (X axis). Two different types of markers are represented: circle filled marker, and squared filled markers. If the marker is a circle, pop upped with a square, it means the best setting found to spread at the considered working width is the absolute best setting in the total matrix, but also a local minimum of one of the

CV curve results (case which occurred for working width between 17 and 23m on the figure). If both circle and squared markers are dissociated, it means the traditional way to determine the best setting does not give the absolute best possible result. It's the case for 28m in the example where 3 different settings can be found as local minimum CV, but where another setting (not a local minimum) allows to reach a best result.

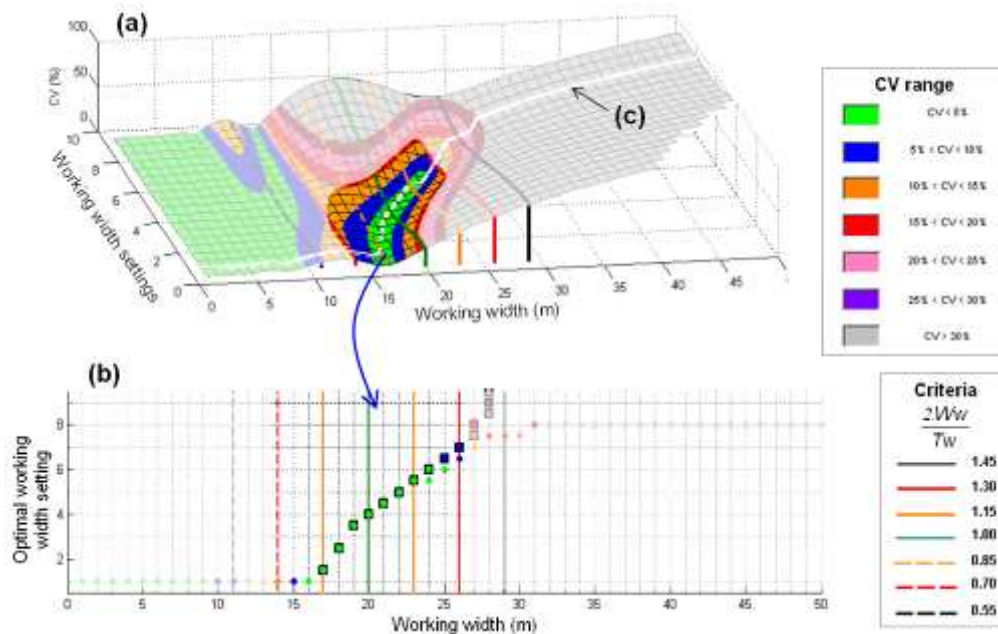


Fig. 7: Illustration of the results obtained using automatic research of the predicted homogeneity distributions (a), and of the extraction of the valuable information to be used by the spreader factory (b).

In addition of this improvement for the setting research process, other criteria are automatically computed and indicated to help factories to draw setting tables. For example, the ratio $\frac{2.Ww}{Tw}$ (Ww is the working width, and Tw is the Throwing width) is drawn for 7 different values between 0,55 and 1,45. It's an indication for the technician to place the spreading pattern area in correlation with the working width. The value $\frac{2.Ww}{Tw} = 1$ means a perfect overlapping will be obtained using this pattern to spread this working width. Higher or lower values mean respectively the pattern is too small or too large regarding the working width. By this way, setting tables can be easily simplified and adjusted to perform the best objectives. The CV value is also not the only criteria to be used, but robustness of the results can also be predicted and associated to reach more accurate results.

The true colored area on the Fig. 7-a and 7-b outlines the best setting area, issued from a combined analyse based on a traditional homogeneity analyse and on the $\frac{2.Ww}{Tw}$ criteria. Two

different analyses can be performed around the robustness side, in order to express the risk to induce local important under or over applications when the tractor trajectory becomes different from the wanted one:

- The bigger is the working width, the narrower is the correct possible setting range allowing working with CV lower than 15% (analyse along Y axis). Working with this couple fertiliser / spreader at such important working widths can be done correctly with a very short range of working width. In this case, a very small modification with the fertiliser (humidity ...) can induce important default applications. This is not the case for lower working widths, where correct results are obtained with a relative large setting range.
- For each spreader setting, the range of possible working widths presents variability. Even if the results show some interesting working possibilities between 16 and 25m (CV < 5%), a

detailed analyse of the 3D graph shows the most robust working width for this example is around 20m and setting 4 because CVs stay less important than 15% in a range of 9m between 14 and 23m (analyse around X axis). For a working width of 17m with setting 1.5, the range becomes narrower (around 5m between 14 and 19m), and for a working width of 25m, the CV deterioration becomes very important as soon as a variation of 1m occurred (26m for example).

3.4. Utility to determine a fertiliser spreading ability

As it has been shown in the previous paragraph, different information have to be crossed together to draw out setting tables because of the number of available settings ... Draw out a fertiliser classification is in the same way a difficult challenge because it must be based on spreading abilities, which are closely dependant to spreader performances one.

The tool presented in the previous paragraph is an answer to this problem because it allows a complete comparison between different fertiliser, using only 1 test bench measurement for every product to evaluate.

The Fig. 8 presents the example of two different fertilisers tested with the same spreader and for which both transverse spread pattern presented are quite equivalent for a 28m working width: fertiliser (1) allows a 3,9% CV homogeneity, and fertiliser (2) 2,4%.

The results obtained using the optimizing tool presented before show higher performances capabilities for fertiliser (1) than for fertiliser (2). Its best range of working width is around 31m while it is 25m for fertiliser (2), and the spreading working width limit using 10% of CV as a maximum accepted heterogeneity reaches 39m for fertiliser (1) while it reaches only 33m for fertiliser (2).

Moreover, this type of tests can be carried out, in the same conditions, but at different time period, and it's a very good way for fertiliser manufacturer to verify regularly the fertiliser improvement on a spreading point of view. It's also a really efficient method to have a quick overview of the different spreading characteristics of many different fertilisers.

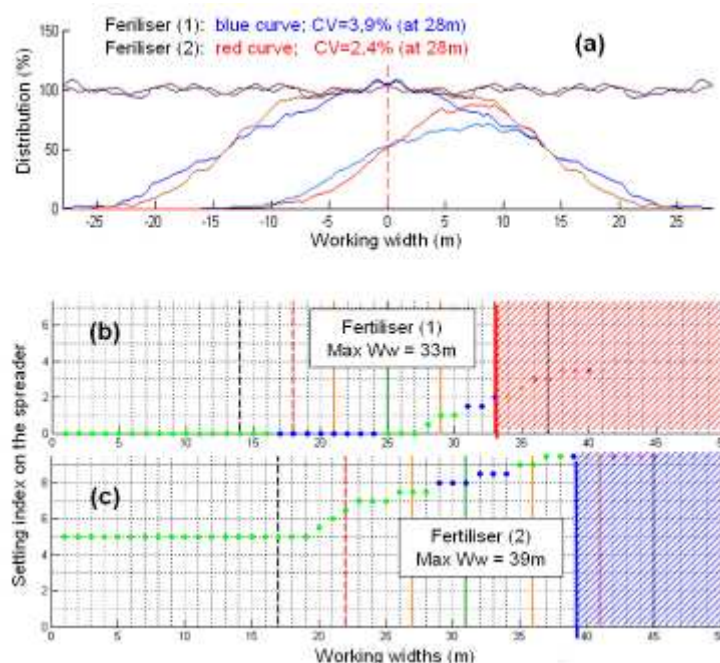


Fig. 8: Illustration of the comparison of 2 fertiliser spreading abilities obtained using the optimization developed tool.

4. Conclusion

This paper shows important new opportunities for developing centrifugal spreader and fertiliser performances. First, the test bench CEMIB, developed by the Cemagref, is an economical device which provides a lot of valuable information in a very short time. The 3D spread pattern which is measured is robust, and represents strong information to start prediction calculations. As the obtained spread pattern is an experimental result, the predictions which can be calculated are very closed to the reality, at least for settings inducing direct effects as the angular drop zone variation, or the disc angular velocity. Complementary works are on the go considering the prediction of setting effects which are less direct, as spreader inclination, vane inclination on the disc ... They need to introduce complementary information as physical comportment laws in the different models, before to be in order to predict setting consequences.

A very important thing is the time consuming to compute the results, which is very small regarding the one needed to perform a real test. It can be assumed that this way of work cannot be replaced by an experimental one, because of the number of needed tests which should be induced.

Complementary analyses are in particular possible as robustness criteria, which represent the base for a "risk analyse", to produce always more valuable information for the technician, the factories (spreader or fertiliser), in order to produce innovations as environmentally friendly as possible. This is possible because the developed computing tools allow establishing specific crossed gauges, using the maximum valuable knowledge content in the measurement.

Over the possibility which is given to develop environmentally friendly innovations, the device to produce these innovations (i.e. the bench and the associated tools) is in itself environmentally friendly. Globally, a lot of crossing analyses can be performed with it, which replace a indefinable number of transverse tests which should be necessary without a good measurement of the 3D spread pattern.

In continuous research development, this global tool is available for eco-design; it can be used as well by spreader manufacturers as by fertilisers ones.

Using the method, the definition of the "fertiliser spreadability" isn't a dream, but can be planned for a near future, as well as a spreader eco-evaluation could be achieved.

5. References

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