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Slug pellet spreading: the double-disc performances available with a single disc spreader

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Abstract

The objectives of this work were to improve the performances of single-disc spreaders used for slug pellets application. The principal aim of this paper is to show the chosen way to reach spreading performances of a dual disc on a single disc spreader. A prototype was developed and evaluated on the Cemib bench at Cemagref. This machinery was designed with an electric power supply to be adaptable on agricultural quad or tractor. Firstly, this spreader allows a working width management without any variation of the disc angular velocity or any added mechanical devices to deflect the output flow of granules. Secondly, a border management is proposed without any mechanic deflector, which should deteriorate the granules integrity. This paper shows in a first part the spreading quality of actual spreaders used by farmers and a second part presents the method used to develop a new innovative eco-designed spreader as well as the performances that are obtained.

Keywords

Centrifugal spreading, Spatial distribution, Radial test bench, Slug pellets

1 Introduction

In France, slugs are considered as a harmful destroyer for crops. Their activities are not limited to regions with mild and humid climate, all regions are touched. Farmers have to protect very quickly their field with a minimum of damage on crops when slugs expand. For this, farmers use small centrifugal single disc spreader for slug pellets application. These spreaders are commonly used because there are very cheap, compact, easy to use and adaptable on a vehicle such as a quad. Many brands sell this type of equipment but there are quite similar in manufacturing. Most spreaders are equipped with a storage hopper in which is disposed only one discharge hole. The spinning disc is placed just under the hopper. The disc is driven by an electric motor powered with a 12V continuous voltage and can reach velocities not far from 3000 rotations per minute.

A single disc spreader makes spread pattern with various characteristics, in terms of mean projection distance and associated standard deviation, regarding the ballistic performances of the product used. The spread pattern shape doesn't allow to obtain a good transversal regularity of the distribution into the field.

Slug pellets are toxics so the distributed products must be spread with a good regularity to limit over-applications and mustn't be spread out of the field to avoid the unnecessary loss of product and for environment respect. Single disc spreaders are often equipped with limited settings. The most sophisticated spreaders are provided with a possibility of disc velocity and drop zone position variation. The angular velocity variation allows the working width modification but can't adequately balance a distribution which is initially asymmetric. At last, this spreader category doesn't present any systems to modify the spread patterns for field boundary applications.

For mineral fertiliser applications, farmers use advanced spreaders, equipped with two discs and which don't present the same defaults. On these dual disc spreaders, both discs rotate in opposite directions. In this way, each disc distributes the same spread pattern on the ground,

allowing obtaining a symmetric and regular distribution. The drop zone position can be modified on each disc so that the working width can be enlarged or contracted. For field boundary applications, these spreaders are equipped with a mechanical system in order to change the granule flow direction or to modify the drop zone position in the border side. For mineral spreaders, the EN13739 standard (EN13739-2, 2003) specifies the necessary requirements in terms of spreading quality.

The goal of this work is to propose technical solutions to correct defaults observed on single disc spreaders used for slug pellet applications. Many spreading principle are derived of dual disc spreaders used for mineral spreading. Originalities of the proposed technologies are to reach the same objectives in terms of working widths variabilities and border management, with a single disc and without any disc angular velocity variations. All the developments are tested according to EN 13739 standard.

2 Defects observed on these machines

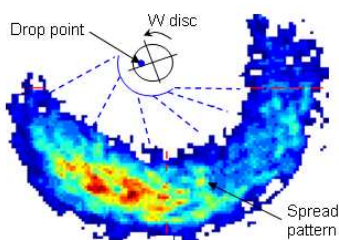
Actual single disc spreaders used for slug pellet applications are very easy to use but they show significant problems in terms of spreading. Actual spreaders present some defaults in terms of symmetry, of working width adaptabilities and do not make possible border settings. The machines are adaptable with difficulty to the products and to the field geometries. Indeed, for each type of granules is associated specific ballistic performances. It is necessary to distribute slug pellets in the concerned areas:

- firstly for reasons of boundary and environmental respect ,
- secondly to avoid unnecessary losses of product which represent a cost.

2.1 Single disc distribution = transversal irregularity

One of the major problems is to ensure a regularity of slug pellets distribution into the field. Actually, with this type of spreader, it's very difficult to obtain a symmetric curve for the transverse distribution. Fig 2.a illustrates this phenomena, the spread pattern presents a shape which looks like a "comet". The greatest density of product is distributed at the beginning of the ejection (the red area at the left of the spread pattern). The consequence is an asymmetric transverse distribution curve which doesn't allow a correct overlapping (Fig 2.b).

(a) – Real measure of slug-pellets spread pattern



(b) – Calculated transverse curve obtained with the slug pellets spread pattern

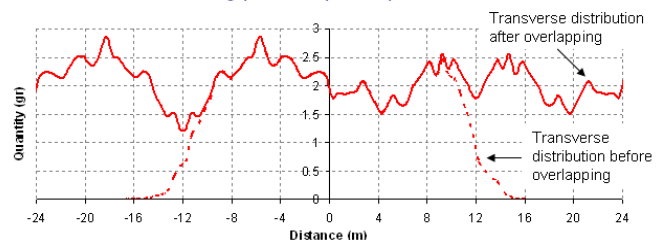
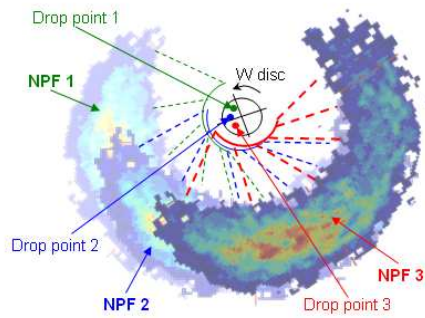


Fig 2: Current irregular distribution obtained with a single disc spreader

The distributed quantity at both sides of the spreader displacement axis is different. The only available setting on this spreader is the balancing of the spread pattern. However, this setting do not make possible to obtain a symmetrical curve; it only gives the possibility to centre as well as possible the spread pattern. This technique, illustrated in Fig. 3, generates, for an angular variation of the drop point position, the same angular variation of the spreading area and then the same variation of slug pellet positions on the ground (Colin, 1997).

(a) – Influence of drop point adjustment on the spread pattern position on the ground



(b) – Influence of drop point position on the transverse distribution

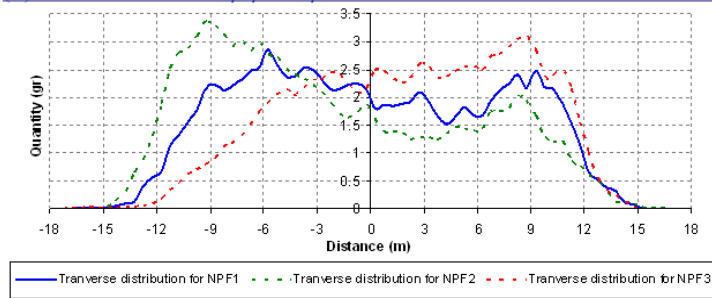


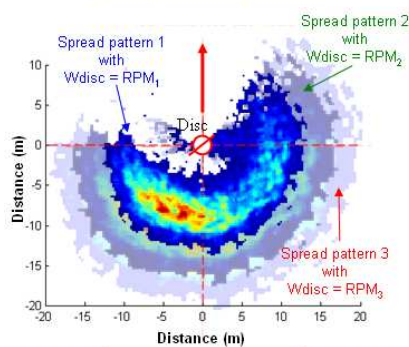
Fig 3: Common single disc spreader adjustment mechanism.

2.2 Variables working widths: not for all single disc spreader

Spreading discs are driven by DC motors. Sometimes, these devices are provided with an electronic control, which sets the disc velocity. The change of spreading disc velocity modifies the projection distance, in the limit of the used product ballistic capabilities (Fig 4.a.b). It also modifies the working width (Fig 4.c). Otherwise, if the machine is equipped with a simplified electronic device, it only allows a constant disc velocity and consequently only one working width, depending on the product used ballistic flight properties.

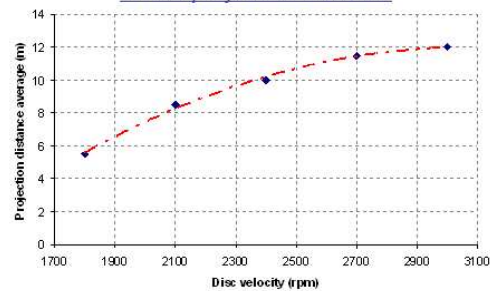
However, in both cases, a major problem remains: the curves asymmetry is maintained and the distribution regularity remains imperfect.

(a) – Influence of disc velocity on the spread pattern position



$$Rpm_1 < Rpm_2 < Rpm_3$$

(b) – Influence of the disc velocity on the projection distance



(c) – Influence of the disc velocity on the transverse curve

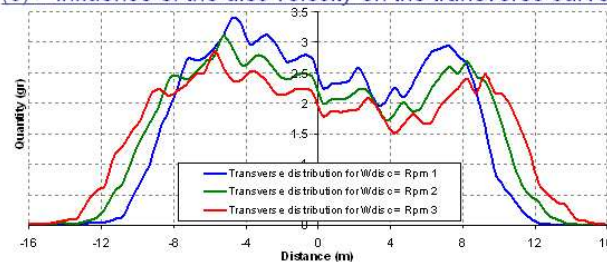


Fig 4: Consequences of disc velocity variation on the distribution

3 Technical responses to increase single disc spreader performances

In this part, the technical principles used to remove these defects are presented. Many spreading principles are derived of dual discs systems used in mineral fertiliser spreading.

3.1 Generalities of the proposed device

The proposed technology manages the working width and the border spreading. For this, the system is able to spread the same product quantity:

- for main field spreading: the product quantity is symmetrically spread between the right and the left side of the spreader displacement axis. Ideally, the total projection width should be closed to around two times the working width, and an overlapping is then necessary between successive runs to reach good distribution regularity (Fig 5.a). In the reality of slug pellets applications, for working widths upper than 21m (depending on the slug pellets), the physical properties of the product doesn't allow to reach this objective. For upper working widths, the shape becomes rectangular, and can, at the limits, look like a "M" shape.
- for border spreading: the distribution presents main-field characteristics in the field side. At the opposite, in the border side, the transverse distribution presents a rectangle shape. The maximum projection distance of the granules is close to the half working width (Fig 5.b).

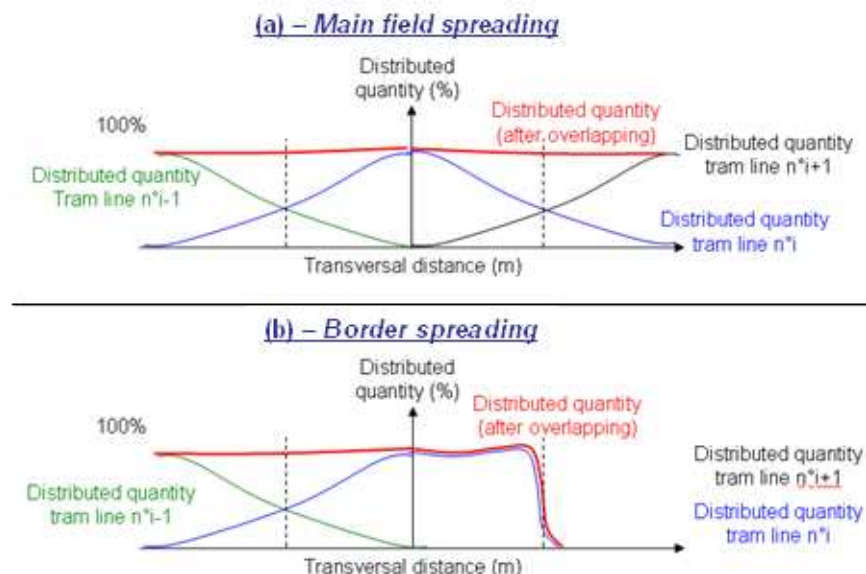


Fig 5: Schematic draw of the researched distributions

The developed principle is based on a system without any variations of the disc velocity whatever the chosen application method (main-field or border mode). The device uses a disc with two different stages; one is used for "main field" applications and the other for "border" applications. In the case of main-field applications, the vanes are placed on a concave disc to increase projection distances. On the contrary, in the case of border applications, the vanes are shorter and placed on a flat disc to limit the projection distance. A selector allows the choice of the working mode (Fig 6).

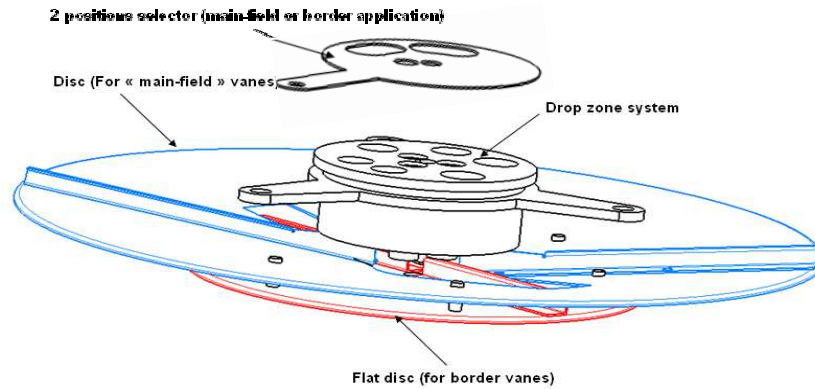


Fig 6: Schematic draw of the disc with two stages, one for main field application (in blue) and one for border application (in red).

3.2 Variable working widths management

The first particularity of this spreader is to manage the variable working width without any variation of the disc angular velocity or any added mechanical devices to deflect the granule flow. The proposed device recreates the same spreading principle as the one used on dual disc spreader: an angular variation of the drop zone generates an angular variation of the spreading sector. Therefore, the spread pattern shapes on the ground changes and the working width also.

On a dual disc spreader, the right disc rotates in the opposite direction of the left one. In this way, the same spread pattern is symmetrically spreading on the ground by each of the two discs. Depending on the desired working width, the spread patterns are closed for low width or otherwise isolated for high working width.

A similar principle adjustment is developed to operate on a single-disc. Instead of having only one drop-point, two separate drop points are disposed on the spreader. The main field vanes (the blue ones used for main field applications) are fed with the product distributed by the two discharge holes angularly adjustable (Fig8.a). The border vanes are isolated; no granules are accelerated by these ones.

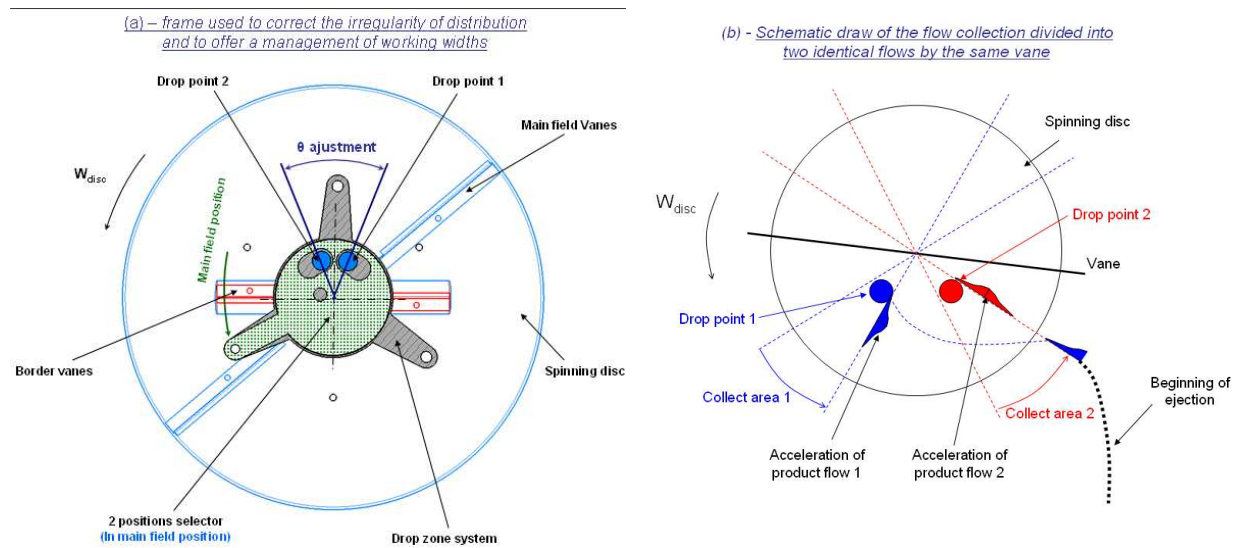


Fig 8: Mechanical device used for the working width management

Thus, the same vane initially collects the distributed product of the first drop point, and then in a second time it collects the distributed product of the second one. The angular adjustment of the two holes allows the acceleration of two flows of products (Fig 8.b). Consequently, two more or less distinct spread patterns are obtained on the ground. At the opposite of dual disc spreaders, these distributions are oriented in the same direction, and the symmetrical compensation can't be perfect, but is significantly improved.

The time interval between the two flows is proportional to the angular space between the two feeding points; consequently, the working width variation is possible (Fig 9).

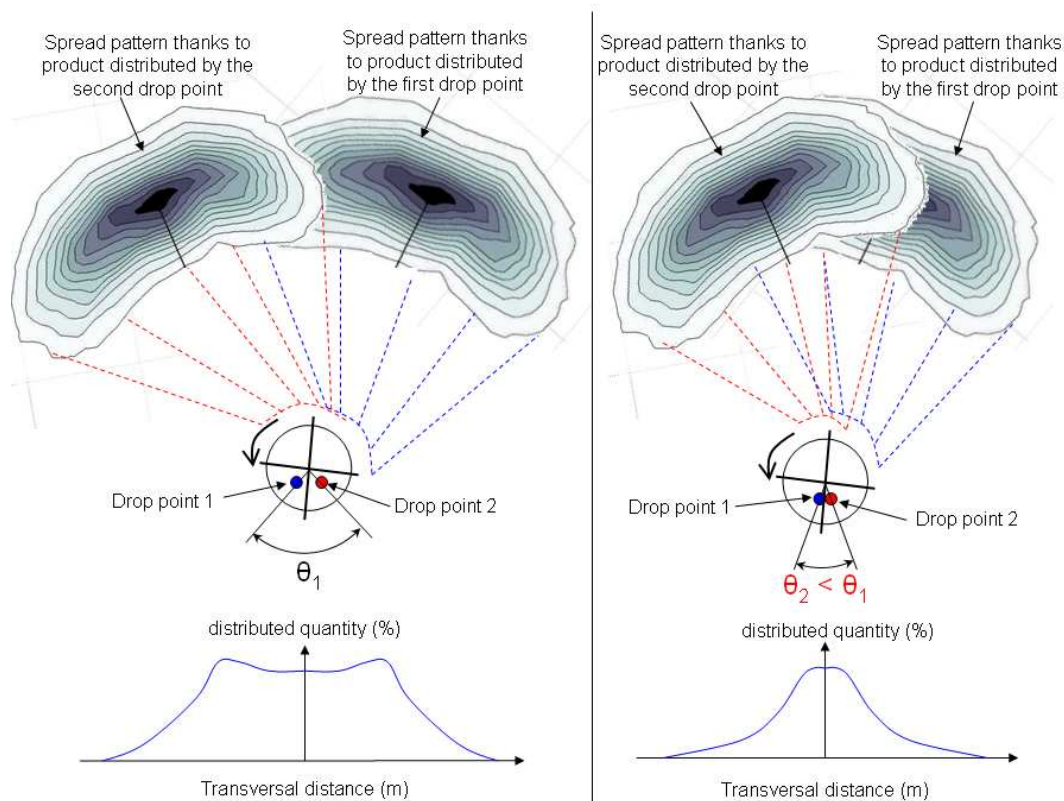


Fig 9: Consequences of different space interval between the two drop points on the spread pattern and on the transverse curve.

3.3 Border settings management

The second particularity of this spreader is to manage border settings without any variation of the disc angular velocity.

For border applications, the mechanical piece "2 positions selector" (see Fig. 10) closes one of the feeding hole used for main field applications and opens a new hole (the red in Fig. 10). This new drop zone is placed at another angular and radial position. All particles distributed by this feeding zone are accelerated by the second stage of spinning disc, flat and equipped with border vanes. The mass flow distributed by the two drop points are equal.

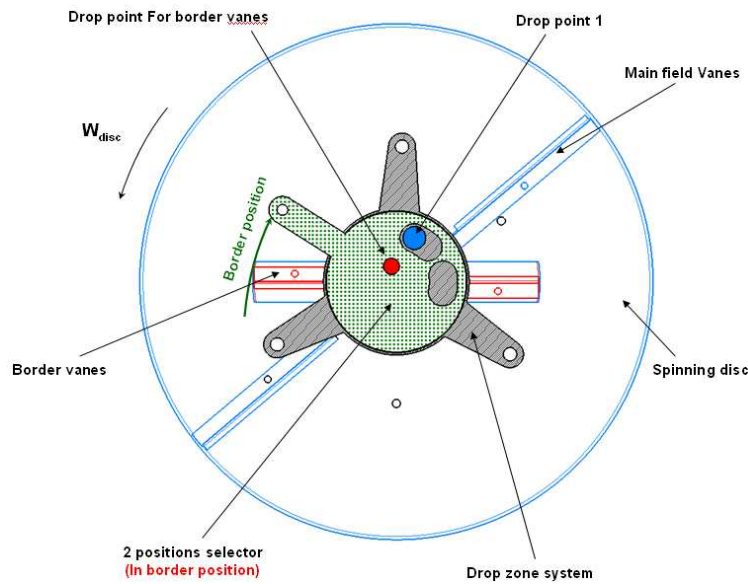


Fig 10: Illustration of mechanical frame used for border management

During this operation, the flow through the "main-field" drop point continues to generate a "main-field" distribution, allowing generating a perfect complementary transverse distribution in field side (Fig 11).

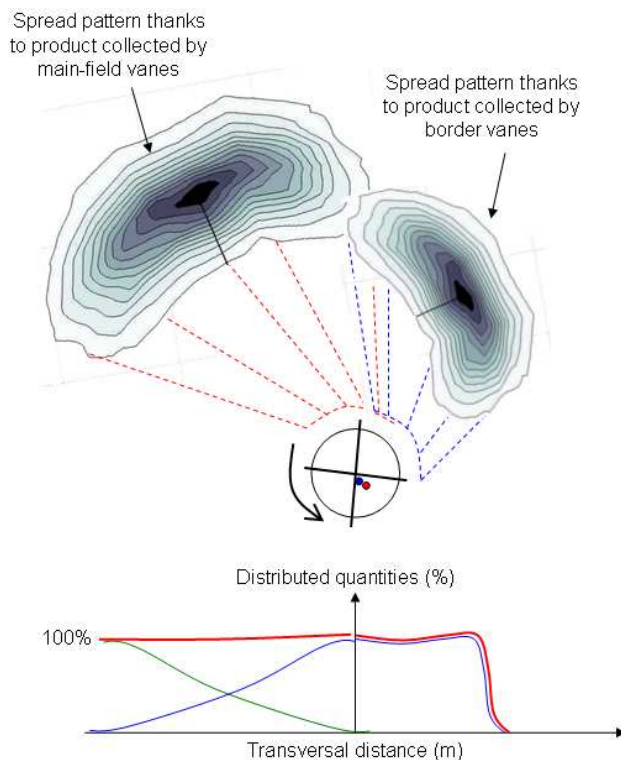


Fig 11: Spread pattern and transverse distribution obtained with border mode selection.

On the contrary, the flow into the "border" drop point generates a different spread pattern with a different angle and a lower projection distance than the one produced by "main-field" mode. Indeed, the flat disc is equipped with shorter vane, allowing lower values as well for the projection distance as for its standard deviation. Consequently, in the border side, the angular position of the spread pattern creates a transverse distribution which looks like a rectangle (Fig 11).

4 Results

A prototype has been developed in 2009 to investigate the improvement of single-disc spreaders using the technical principles described before. All the experiments have been carried out at the CEMIB, shorter for CEMagref Mineral Bench (Piron and Miclet, 2005, and Piron, 2007). Data have been processed according to EN 13739 standard.

Figure 12 summarizes some results obtained for three different working widths. The three presented working widths are 18, 21 and 24 meters. The proposed device for working width variation works as expected, obtaining dual disc comparable results. The results indicated a significant effect of the angular space between the two drop points on the spread pattern. Depending on the angular space between the two feeding holes, the spread pattern space between each one is closed for low widths or otherwise isolated for high working widths.

Moreover, with two drop points in the case of main-field applications, all presented curves are almost symmetrical as shown in figure 12 in regard with the distributions produced by actual single disc spreaders (Fig 2). The major default of symmetry is corrected by this system.

So, with this two application points, we obtained a good regularity of spreading. To satisfy the standard EN13739 (mainly valid for fertiliser spreaders), the transverse distribution C.V. should be less important than 15%. The presented development allows CV less important than 10% for working widths between 12 and 24 meters.

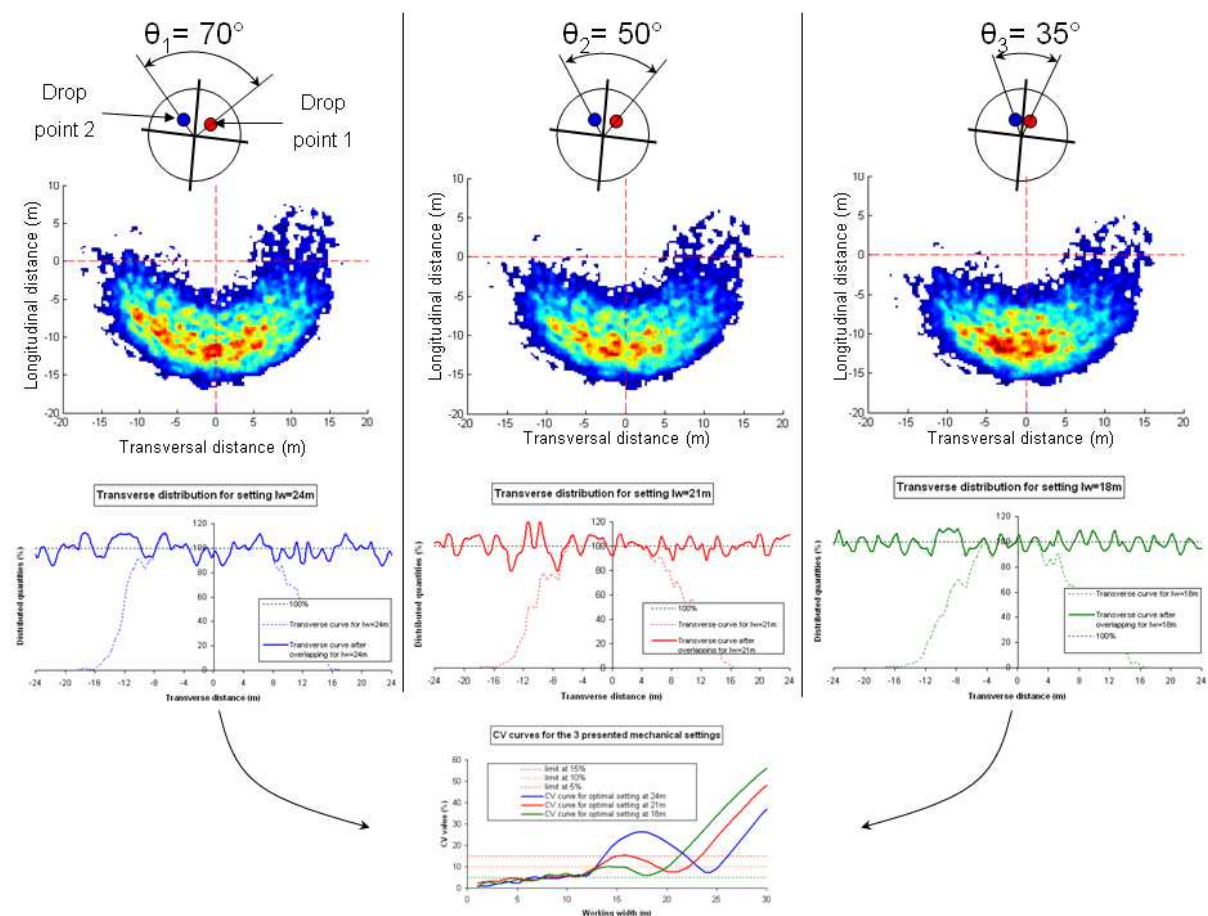
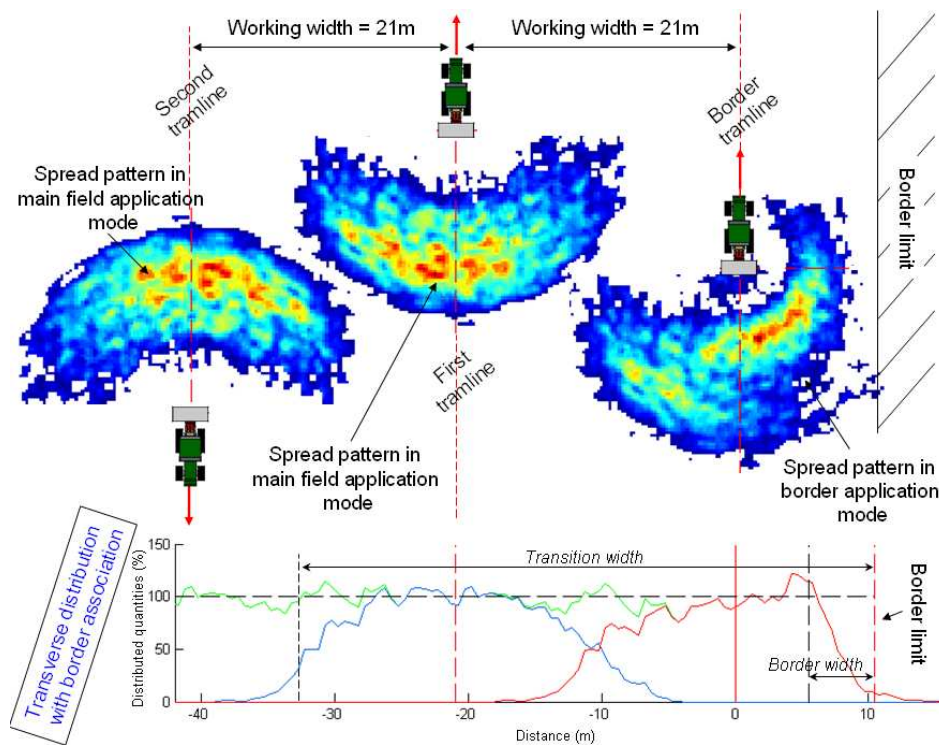


Fig 12: Results concerning the transverse distributions with different working width settings

Figure 13 summarizes the results obtained for border applications. The technical proposal for border management gives satisfaction. The results indicate a significant effect in terms of projection distance for the particles that are taken up by “border vanes” (mean projection distance approximately equal to 7 meters). For the particles that are taken up by the “main field vanes”, the projection distance remains the same than the one used for main-field application (mean projection distance close to 12 meters).

Without any variation of the disc velocity, the spreader can satisfy the EN13739 standard as shown in figure 13. To satisfy this standard, three criteria should be checked. No fertiliser should be spread out of the field. This requirement is fulfilled when the fertiliser quantity out of limit is less important than 3‰, which is the case here. At any point of the border width, the application rate mustn't exceed 120% of the main field average application. In our case, this criterion is satisfied. Finally, the coefficient for the transition width doesn't exceed 25% as required in the standard (Fig 13).



Quantity out of the field: 1.37‰
Coefficient for the transition width: 22.73%
Border limit : 5.00 m
Field C.V.: 7.61%
Max. of application rate in regard with the average rate on border limit: 13.07%

Fig 13: Results on transverse distributions for border applications

5 Conclusion

The study shows that it is possible to increase performances of centrifugal spreading with a single disc spreader. The technical proposal eliminates the defects encountered on actual single disc machines: the main dissymmetry of transverse distribution, the single working width, and the spreading of particles out of the field. All these developments are done without any variation of the disc velocity or any added mechanical devices to deflect the output flow of particles. The spinning disc uses two stages to make possible the management of the working width and the border spreading. The variation of the working width is achieved by an optimal position of two separate drop points. The border application is obtained using the second stage of the disc (flat, equipped with short vanes).

The performances of the developed spreader give satisfaction according to EN 13739 standard. The spreader works with a working width and a border management as well as a dual disc spreader. It is possible to work between 12 and 24 meters for the working width with a coefficient of variation into the field lower than 15%. The fertiliser amount spread out of the field is less important than 3%. No border point receives a rate higher than 120% of the main field average application rate. Moreover, the coefficient for the transition width doesn't exceed 25%.

The main principle developed and used on this specific spreader, i.e. the working width device and the border one have been patented in 2009.

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