CHALLENGES FACING CONTEMPORARY SEED DRILLS FOR REDUCED TILLAGE, REVIEWING VARIOUS TECHNICAL SOLUTIONS AND DISCUSSING A METHOD FOR EVALUATING THEIR EFFICIENCY

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Abstract: *There are significant benefits to be gained from reduced and no-tillage in connection to soil protection policies but the unique requrements of such practices create the need for seed drills capable of matching these requirements. It is necessary to reach a quantative representation of the effectiveness of different brands of seed drills in order to chose a suitable drill for the task. The seed drill's efficiency can be judged after the biological and economic risks of its usage have been evaluated. This paper shows a method which uses the technical data of the seed drill and reaches a cumulative grade to evatuate the biological risk and also an existing software which compares and evaluates the economic risk for a chosen seed drill compared to Cross Slot seed drill. Combining the two types of risk evaluation lets us chose the best type of seed drill for seeding in reduced tillage.*

Keywords: SEED DRILL, REDUCED AND NO-TILLAGE, EVALUATING EFFICIENCY, BIOLOGICAL RISK, ECONOMIC RISK

1. Introduction

Soil protection has a unique look due to a number of advantages it offers such as improved economy of production; increased organic content and higher quality of the soil; reduced labour costs, assets, machinery and fuel lubricants; improved water balance in soil; reduced erosion processes; increased percentage of plant nutrients; improved environment[1,5,7,8].

The incorrect application of reduced tillage technologies hides potential risks. The risk components with reduced tillage are:

- Biological risks – referring to stress situations through disease and pest attacks, toxins and nutrient stress, reduced vitality of the seeds, etc.;
- Physical risks – referring to climate changes, preparing appropriate seed bed and efficiency of the whole machine;
- Chemical risks – referring to providing sufficient and timely nutrients, particularly hazards of "burning" seeds as a result of incorrect fertilisation, effective application of pesticides, etc.

Properly selected, the seed drill for direct seeding directly reduces the physical risk, and indirectly – all other risks factors. As a final result, the economic risk is reduced[5].

2. Distinctive features of seeding in soil protection agriculture

No-till has answered many of the problems arising from modern agriculture but the main reason it was introduced on a large scale in some regions was to fight soil erosion. Soil in its natural state in nature without human influence is much more resistant to water and wind erosion alike. The development of no-till followed an adaptation of existing in conventional tillage seeding openers to the specific requirements of no-till. Such are the disk openers which make a V-shaped slot and the hoe-type openers that create a U-shaped slot. Only one - a third one - has been specifically developed for no-tillage seeding purposes - the inverted T-shaped slot, achived with a central vertical disk and two subsurface wings on both its sides[5]. All three types are intended for seeding in the conditions of soil protective agriculture. In our country they are known as seed drills for direct seeding. The similarity of traditional seed drills to those for direct seeding is only superficial since they operate in different conditions. Their distinctive features are:

- **condition of the soil** – there is minimal or zero impact on the soil and its surface is covered by a significant amount of residue or live plants;
- **construction** – the seed drills for direct seeding are mostly of the combined type, which reduces the total number of passages of agricultural aggregates over the soil surface. The seeds are laid in the soil mostly by cross slot seed boots, which provide a greater amplitude of deviations in the vertical plane.
- **energy needs** – attachment to more powerful tractors is required due to the larger technological mass and the higher soil resistance.
- **economic indicators** – the seed drills for direct seeding are more expensive and have higher maintenance costs, but this is compensated by the significantly lower cost of harvested crops.

The choice of a seed drill for direct seeding should start with assessment of the difficulties, arising from the application of soil protection technologies. The ability of the seed drill to overcome these difficulties is the precondition for its efficient use.

- With reduced tilling, the field surface is more uneven and in order for the seed boots to have better coverage, they should have a greater amplitude of deviations in the vertical plane;
- Ability of the seed boots to adapt continuously to the natural change in soil hardness in such a way that they penetrate to the same depth every time
- Incorporating of fertilisers with seeding should be carried out with clear distinction between fertiliser and seed placement, in order to reduce the biological risk of "burning" the seeds.
- The presence of residue on the field surface requires the seed boot not only to prepare an appropriate seed bed, clean of residue, but also to be able to control (to move) the residue in such a way that it will remain close to the planted seeds.

3. Technical solutions for seed drills for direct seeding

Most of the technical solutions, used in the seed drills for direct seeding are known in the traditional seed drills as well, but their abilities should not be exaggerated when it comes to direct seeding[5,7]. The main challenge that the seed drills for direct seeding face is the shape and state of the seed bed, formed by their boots. The most appropriate one turns out to be the inverted T-shape, which is achieved by two types of seed boots:

- **Cross slot seed boot** - it is a straight smooth disc with symmetrically placed cutting wings on both sides (see Fig. 1). The disc cuts the soil vertically and the cutting wings - horizontally. Thus, the cross section of the seed bed takes the shape of a cross (see Fig. 2)[10].

Fig. 1. *Sowing section with cross slot seed boot*

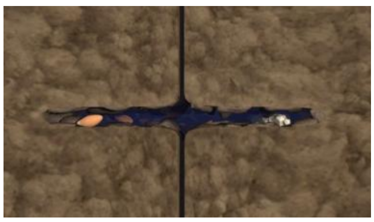

Fig.2. *Shape of the seed bed made by cross slot seed boot*

The seed bed formed has a wide bottom, longitudinally cut by the disc, with the seeds laid in one half and the fertilizers – in the other. The result is a seed bed clean from residue, with good soil structure around the seeds – dense bottom, a suitable loose top layer and ensured inflow of water and air. The strip planted with seed, remains covered with the plant residue. These seed drills allow seeding at higher operational speed and maintain the set depth of sowing, but have a higher drag.

- **Baker boot -** the shape of the boot resembles universal arrow-like slot with a seed line attached to its end (see Fig.3). It creates favourable environment for seed germination and sprouting, but is subjected to relatively quick wear and tends to collect plant residue on its surface. This kind of boot does not allow separate laying of seeds and fertilisers. Fertiliser is introduced by separate tools at a depth different from that of the seeds (See Fig.4[5,7,11].).

Fig. 3. *Seeding section with baker boot and a cutting blade before it*

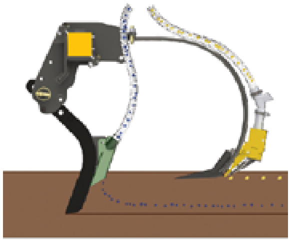

Fig. 4. *Laying of fertilisers and seeds*

Both types of boots are suitable for both drier and wetter soils of all kinds. The T-shaped form of the seed bed retains the available humidity around the seeds planted when it us scares while keeping the plant residue above the seeds and the soil condition around them activate earth worms at higher humidity (see Fig. 5) [10].

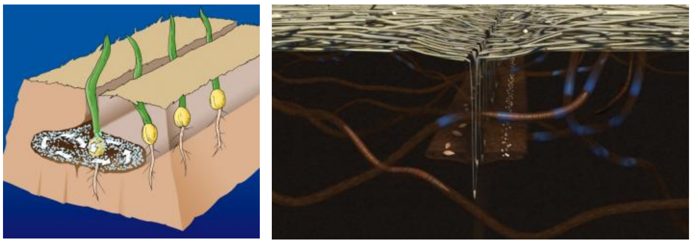

Fig. 5. *Strengths of the inverted T-shaped seed bed*

An important moment of the operation of all seed drills is their maintaining the set depth of seeding. The most popular way for this is using support wheels.

- Individual control – a more precise depth control is achieved when the seeding section is equipped with (a) support wheel(s), close to the seeding boot. This is widely used with seed drills for direct wide-row seeding (see Fig.6) and its popularity is growing also with seed drills for direct row seeding[2,3,4,5,10] (see Fig. 7).

Fig. 6. *Seeding section for wide row seeding*

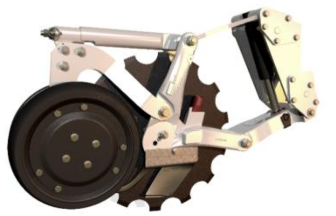

Fig. 7. *Seeding section for row seeding*

- Group control – It facilitates the maintenance of the seed drill, but it can't maintain the depth of each boot in the row(s) of seeding boots properly (see Fig. 8), especially with large working widths of the seed drills and uneven fields. The support wheels are usually displaced in terms of the seeding boots line[2,3,4,5].

Fig. 8. Group control of seeding depth with seed drills for direct row seeding

Maintaining the seed boots in a fixed position to the field surface is related both with the seeding depth and their drag and balance during operation. Thus the way of attaching the seeding boots to the frame and the means of putting additional pressure on them is important.

Fixed suspension on spring stand – the elastic forces of the spring stand help the digging and maintain the balanced position of the boot, but they can't cover large bumps on uneven fields. (see Fig.9)[11].

Single hinge suspension – the long supporting arm of the seeding section guarantees the proper digging moment of a small mass seeding boot. Once taken out of balance, the boots suspended in this way take longer to return to balance again. That is why single hinge suspension sections need additional mechanical or hydraulic pressure (see Fig.10)[11].

Fig. 9. *Fixed suspension on spring stand*

Fig. 10. *Single hinge suspension*

Multiple hinge suspension – suitable for attaching heavy seeding sections and allowing excellent coverage of field surface even where there are bigger bumps. With such suspension, the seeding boot recovers its balance faster when needed. The inclusion of additional devices for monitoring and control of the pressure makes the movement of the section automatic and the operation of the boot even more precise (see Fig.11) [10].

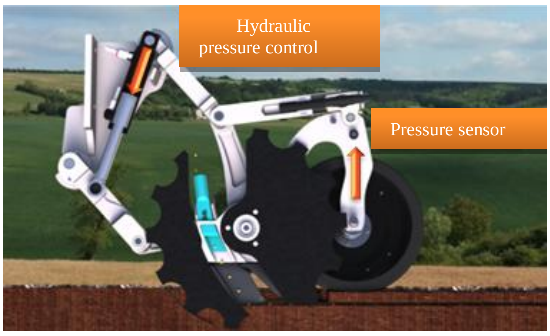

Fig. 11. *Multiple hinge suspension*

The dense soil, uneven soil surface and plant residue are a challenge for the seed drills for direct seeding in terms of the depth of sowing. Using automated control systems for pressure control contributes to the consistent depth while seeding, no matter what the conditions are (see Fig.12).

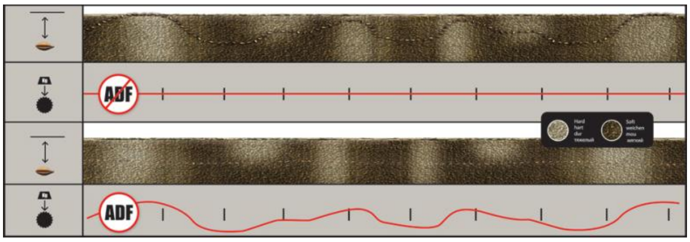

***Fig. 12**. In-depth seed layout without using the automated pressure control system (above) and with using such a system (below)*

An alternative solution for keeping a constant seeding depth is the usage of a cultivator section which tills only the part of the field, where the seeds will be placed (Fig. 13)[6]. This equalizes the soil physical properties in the seeding zone, which benefits the stability of the seeding sections during operation even without the usage of automated pressure control system. This added feature also contributes to the reduction of biological risk when using disk and hoe openers in direct seed drills but increases the seeder weight and thus its drawing resistance. '

***Fig.13.** A cultivator section wuth star wheels attached to a direct seed drill*

4. Considerations before choosing a seed drill for direct seeding

The choice of a seed drill for direct seeding should start with assessment of the difficulties, arising from the application of soil protection technologies. The ability of the seed drill to overcome these difficulties is the precondition for its efficient use.

- With reduced tilling, the field surface is more uneven and in order for the seed boots to have better coverage, they should have a greater amplitude of deviations in the vertical plane;
- Ability of the seed boots to adapt continuously to the natural change in soil hardness in such a way that they penetrate to the same depth every time
- Incorporating of fertilisers with seeding should be carried out with clear distinction between fertiliser and seed placement, in order to reduce the biological risk of "burning" the seeds.
- The presence of residue on the field surface requires the seed boot not only to prepare an appropriate seed bed, clean of residue, but also to be able to control (to move) the residue in such a way that it will remain close to the planted seeds.

5. Evaluating the effectiveness of the seed drills for direct seeding

The seed drill's efficiency can be judged after the biological and economic risk of its usage has been evaluated. The technical specifications of the seed drill are crucial in risk evaluation. An

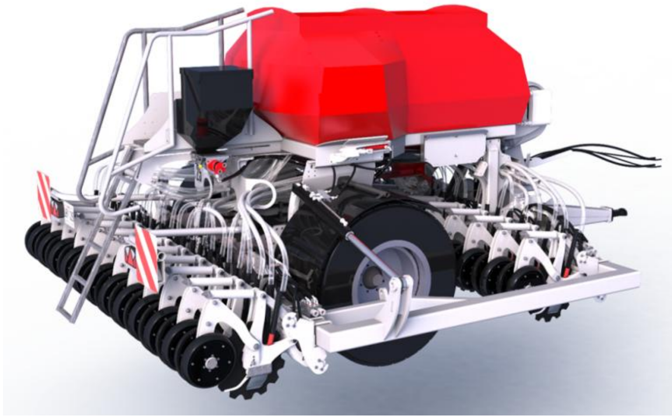

***Fig. 14.** Seed drill for direct seeding*

example estimate is presented for the seed drill for direct seeding shown in Fig. 14.

The economic risk has been calculated by the method presented in section 5.1. below, while evaluating the biological risk is discussed in section 5.2.

5.1. Evaluating the economic risk

The economic risk can be determined by ready-made software. An example for evaluating the economic effect of using any brand of a seed drill for direct seeding compared to Cross Slot drill is presented in a table here [10]. The table takes into account the innitial investment cost as well as operational costs and compares them between the two seed drills.

Using seed drills for direct seeding requires higher investments. Evaluating the economic effect by using an electronic calculator allows entering specific values, concerning the seed drill and the production technology. The economic evaluation is presented at the end of the table with three results and a commentary, making it clear where the right decision making should be directed. Often the higher purchasing cost of the direct seeding drills is later more than compensated by the higher yield these machines achieve - which is reffered in the table as the yield-cost advantage.

5.2. A convenient methodology to evaluate the biological risk

A convenient way to evaluate the seed drills for direct seeding is the methodology presented in Fig. 15 [7]. It refers to the functional abilities of the seed drill to reduce to a certain extent the biological risk, which can emerge when seeding with reduced tillage. The criteria (abilities) included in the evaluation arise from the above-mentioned preconditions, each criterion changing from 1 to 10 depending on the technical solution, which has been chosen during construction of the seed drill. The smaller the number under which the technical solution stands, the smaller the estimated biological risk is.

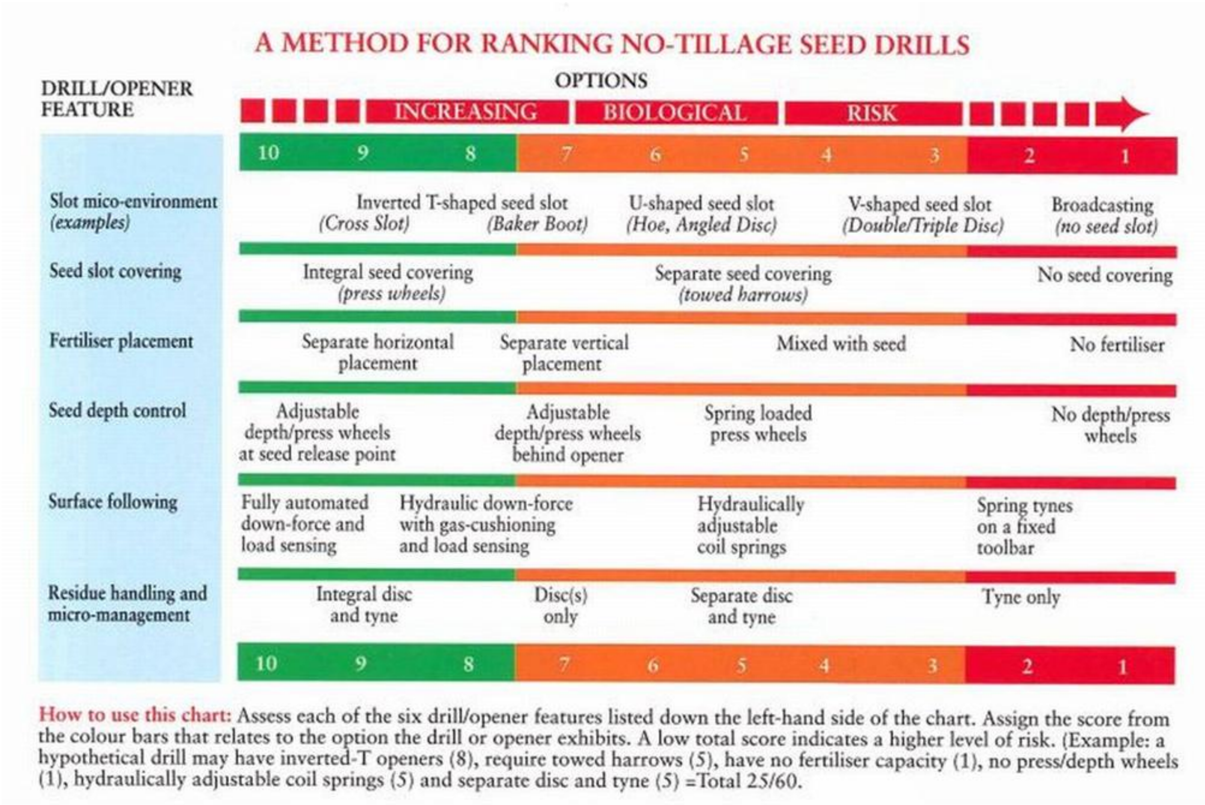

Fig. 15. *Method for classifying the seed drills for direct seeding*

The biological risk has been assessed in the following way, using the methodology mentioned:

The official data for the assessed seeding machine is considered. As an example of how the evaluation chart works, we take the data for the T-Force© Series of the company NOVAG SAS [9]. In engineering and execution it meets some of the criteria described in Fig.15. If the seed drill machine meets the requirements in columns 1,2 and 3 (green), then for each row from Fig. 14 we get the following values:

- With seed bed shape – inverted T-shaped after using cross slot boot (Grade 2).
- Burying the seeds – immediately with a pair of V-shaped depth/press wheels (Grade 2).
- Introducing fertilisers at the same time as sowing – the type of seed boot used allows horizontal introduction of fertiliser separately from the seeds (Grade 2).
- Sowing depth control – carried out by a pair of depth/press wheels, mounted close to the boot (Grade 2).
- Covering of the terrain– fully automated control of pressure and drag (Grade 1).
- Moving the plant residue – by the disc and tine of the boot (Grade 4).

The cumulative grade from the six criteria is equal to 13. The higher this grade is, the bigger the biological risk. The maximum risk is 60 points. It the sum total is divided by the maximum risk, we get – 13/60=0.216, i.e. about 22% is the probability of disturbing the biological productivity of plants, just from applying the selected seed drill. This risk varies for the different constructions of seed drills from 10 to 90 %**.**

6. Conclusion

The unique requrements of reduced and no-tillage create the need for seed drills capable of matching these requirements. Evaluating the effectiveness of a seed drill can be accomplished only after evaluating separately the biological and economical risks connected with the usage of the seed drill. The biological risk can be evaluated using a method taking into consideration the construction of the machine and giving each technical solution a numeric equivalent. These are then combined and transforemed into a single number which represents the overall risk of disturbing the biological productivity of the plant by using the selected drill in percentage. The economic risk can be evaluated by using a developed software to make a comparisson between the cost of two machines and the yield-cost advantage of one of them. Combining the evaluation of the biological and economic risks makes it possible to choose the most suitable and efficient seed drill to answer the unique requrements of seeding in conservation agriculture.

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