Scarification of Seeds as an Increasing Element of Perennial Legume Grasses Productivity

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Abstract: Technology and principle of disk-type seed scarificator operation for seed treatment of perennial legume grasses are given. Parameter – level of mass loss during the friction on scarifying disk – M, % is introduced for quality assessment of scarification efficiency. During the researches it was revealed that mass loss of sowing material the highest sowing characteristics 20% are shown, further increasing of mass loss results in excessive seed damage and its sowing quality.

1. Introduction

The national project of Russia in the field of agriculture provides for intensive development of livestock-breeding. In common process of livestock-breeding production more than a half expenses falls to the share of forage [1].

In the conditions of sub-boreal forest zone of the Western Siberia the most important specialization of agriculture is livestock-breeding. In this connection, supply the cattle with high quality feed is very actual task. Subboreal forest zone has always been the zone of risk arable farming. For stable livestock-breeding development in this zone great attention must be paid to the efficient technology of annual and perennial grasses cultivation [2].

One of the sticking points of expansion perennial legume grasses on the farms of sub-boreal forest zone of the Western Siberia, particularly in Omsk region is the failure in seed preparation technology for sowing such important practice as scarification.

Scarification is directed to destroy to a greater or lesser degree the layer of palisade cells of hard seed-coat, to deprive their leakproofness and to open the access of water and oxygen inside the seed. Attention to the qualitative presowing seed treatment of perennial legume grasses is explained by great potential of increasing their yields, necessity to create the conditions for complete realization of seed potential, opportunity to reduce the sowing rate using modern varieties, reduction of expenses on unit of production. However scarificators used at present time do not correspond to agrotechnological requirements. In order to obtain qualitative presowing treatment it is necessary to use scarificator with lower frictional disk and dosing unit for even seed delivering [3, 4, 5].

The aim of our research is to study scarificator effectiveness of perennial legume grasses seeds, influencing on seed quality and yielding of herbage in the conditions of sub-boreal forest zone of the Western Siberia (for example Omsk region zone).
For achieving this aim it is necessary to solve two main tasks:
To develop scarificator with lower frictional disk and dosing unit for even seed delivering.
To reveal the effectiveness of seed scarification usage, influencing on field germination rate and yielding of herbage.

2. Object and methods of investigations

Investigations are carried out in two stages:
- the first stage – the development of scarificator. Dosing roller is adjusted in hopper bottom with the aim for even seed scarification and exception of mechanical damages and for seeds delivering on the scarifying element evenly. Distribution cone is also adjusted in it for even seed distribution on scarifying disk. To provide qualitative seed treatment scarifying disk is closed by upper disk which can move in vertical plain, providing essential gap between disks for even treatment of the seeds.

- the second (field) stage is connected with studying of seed scarification influence of perennial legume grasses (eastern galega and red clover) on field germination rate and yielding of herbage. Field investigations are carried out in 2010 – 2015 in sub-boreal forest zone of Omsk region on grey forest, medium loamy soils with low content of nitrogen, medium – phosphorous and potassium. Field experiments are carried out according to the methodological instructive regulations. Plot area is 36 m2 (registration plot – 24 m2), distribution – randomized, frequency – quadruple. The following sowing variants of eastern galega (factor A) and red clover (factor B) are studied: 1. Sowing without seeds scarification; 2. Sowing with scarified seeds. Sowing is done under winter wheat. Yield data are processed by dispersive, correlative methods and regression analyses in B.A. Dospekhov’s statement as well using personal computer in spreadsheet Microsoft Excel [6, 7].

3. Experimental investigations

Method of mechanical impact on hard seed-coat of legume grasses is the simplest and acceptable for productive conditions during the treatment of considerable part of seed material. Different machines (clover grater, hammer crushers, different kinds of awners) are often used in practice for reduction of hard seed quantity, specially are not intended for scarification. Owing to in most cases negative results due to seed embryo damage during their treatment process have been obtained. Usage of these machines is explained by less importance to seed scarification in connection with long use of legume grasses. Therefore due attention was not paid to the construction of special machines - scarificator, but developed and made devices have a number of essential disadvantages, namely not fully provide high quality and often damage the seeds during their treatment process [8].

From here need of seed scarificator improvement follows with the aim to eliminate above - noted disadvantages.

Structural scheme of experimental scarificator is shown in the figure 1 [9].

**Figure 1.** Scarificator scheme: 1 – hopper; 2 – dosing unit; 3 – housing; 4 – additional disk; 5 – scarifying disk; 6 – outlet opening; 7 – frame; 8 – electromotor; 9 – V-belt transmission; 10 – revolution indicator; 11 – cone; 12 – gear; 13 – screen.

Housing of scarificator consists of three units (figure 2):
I. Seed drill tube with the cone rotating inside.
II. Operation chamber (fixed disk and moving disk with rough surface).
III. Tapered receiver.

At first seeds in free fall (under the influence of gravity) move along the seed drill tube and get on the cone then move downward in two ways: slide on cone sides or experiencing a number of impacts with cone sides and upper disk, roll downward. From the cone seeds fall on the rotating disk. Receiving the impact of rotary movement, seeds under the influence of centrifugal forces roll from rotating disk and get in tapered hopper-receiver. Rolling on the walls of receiver, seeds get in the store.

We choose the main parameters of experimental scarificator proceeding from previous investigators. Disk grating device was taken for an initial design as the most efficient. This design belongs to M.I. Borisov and at first time it was used as an analog of creation experimental unit. This choice is explained by technological scheme put in this device allowing to increase qualitative indexes.

In a basis of the choice of experimental unit parameters following characteristics were taken:
1) feeding of experimental scarificator;
2) radius of rotary disk (rotor);
3) parameters of rotary cone;
4) frequency of disk (rotor) rotation;
5) rough of upper part of rotary disk (rotor);
6) height of crack (gap) between fixed disk (cover) and rotary disk (rotor).

Load of experimental scarificator depends first of all upon the ratio of radius of rotary disk (rotor) and the radius of cone, size of grain as well the rate of disk rotation and crack (gap) size between fixed disk (cover) and rotary disk (rotor). Considering that crack (gap) size is selected in compliance with the size of scarified seeds (it can not be large - some part of seeds won't be scarified and can not be small - flow capacity is reduced), we'll vary its size in further researches.

Figure 2. Scarificator scheme with instructive regulation of attachments: 1 – receiver (hopper), 2 – rotary disk (rotor), 3 – fixed disk (cover), 4 – rotary cone, 5 – seed drill tube.

Therefore with concrete frequency of disk rotation \( n \) we consider that load depends on (is direct ratio) ring size with external radius - \( R2 \) and internal – \( R1 \) (figure.3).
Figure 3. Technological scheme of scarificator

Consider the main parameters of scarificator: \( R_2 \) – external radius of rotary disk, \( h_2 \) - height of crack between fixed disk (cover) and rotary disk (rotor). \( V \) - linear rate of grain motion when escaping from operation chamber. It depends upon the rough ratio of rotary disk (in our case the rough ratio will consider in ratio of surface efficiency \( \eta \)) and frequency of disk rotation \( n \), \( P \) - grain density located on disk edge (it is less than grains density falling on the disk near the cone). For quality assessment of productivity we chose the following meanings: \( R_2 = 200 \) mm, \( h_2 = 4 \) mm, \( V = 400 \) m/h (linear rate is defined experimentally and corresponds to 600 rpm), \( P = 664 \) kg/m³.

The density \( P \) is counted from seed bulk density \( P_{\text{h}} = 780 \) kg/m³ according to the following scheme: knowing seed bulk density \( P_{\text{h}} \), we can find seed mass located on small ring (from \( R_1 \) to \( R_1 + \varepsilon \)) near the cone (here \( \varepsilon \) – increase of radius size used for ring formation). We’ll obtain calculation formula as the product of ring size on the height of crack (gap \( h_2 \)) and on the seed bulk density \( P_{\text{h}} \):

\[
m = \left( \pi \cdot (R_1 + \varepsilon)^2 - \pi \cdot R_1^2 \right) \cdot h_2 \cdot P_{\text{h}}
\]

(1)

On the other hand this is the same seed mass during disk rotation will be located in some volume, defined by ring on disk edge:

\[
W = \left( \pi \cdot R_2^2 - \pi \cdot (R_2 - \varepsilon)^2 \right) \cdot h_2
\]

(2)

Considering the fact that:

\[
m = P \cdot W, \text{ unknown density } P = m / W.
\]

(3)

\[
P = \frac{(R_1 + \varepsilon)^2 - R_1^2}{R_2^2 - (R_2 - \varepsilon)^2} \cdot P_{\text{h}}
\]

(4)

Scarificator load is defined on the given parameters \( Q = 63 \) kg/h.

On the basis of above taken for scarificator project we use following parameters:

1) we consider sufficient load of experimental scarificator - \( Q = 63 \) kg/h;
2) radius of rotary disk (rotor) we set to equal 200mm;
3) parameters of moving cone we define from the size of polyethylene seed drill tube (its radius – 50 mm): radius of cone basis \( R_1 = 120 \) mm, height of cone \( h = 90 \) mm;
4) frequency of disk rotation (rotor) \( n \) from 400 rpm to 1600 rpm.
5) rough of upper part of rotary disk (rotor) we’ll characterize by parameters \( E \), which is the measure of grainy of operation surface \((16 \leq E \leq 50)\), moreover the surface is rough \( E = 50 \) mkm, and \( E = 16 \) mkm surface is soft (GOST 3647-80);

6) height of crack (gap) between fixed disk (cover) and rotary disk (rotor) we define from seed size \((3.6; 1.8; 1.3)\) and we’ll set to \( h2 = 4 \) mm;

7) sizes of receiver (hopper): radius \( R3 = 250 \) mm, height \( L1 = 250 \) mm, radius of lower ring \( R5 = 50 \) mm.

8) material of receiver (hopper) – rubber, steel;

Quality assessment of scarified surfaces is done according to degree of seeds scarification. Degree of seeds scarification \( (S) \) is defined according to the formula:

\[
S = \frac{a-b}{a} \cdot 100\%
\]

where: 
- \( a \) – quantity of hard seeds before treatment, \%;
- \( b \) – quantity of hard seeds after treatment, \%.

In comparative quality assessment of each scarified surface we used its efficiency ratio \( (\eta) \), counted according to the formula:

\[
\eta = S \cdot [1 - \rho],
\]

where: \( \rho \) – damage degree (crash), \%.

The effect of scarification is achieved by relation of seeds with rough surface of the disk. In operation chamber the seeds always contact with rough surface of the disk, herewith lack of seeds relation together and surface scantiness in operation chamber do not create additional obstacles for scarification.

Under the influence of centrifugal forces the seeds take off from operation chamber and roll down along the curved surface of upper disk (under the gravity and failing centrifugal forces) to the laprobe of receiver (hopper), and then is prevented the stroke of seeds against its walls.

For quality assessment of scarification during experimental researches we apply parameter – the degree of mass loss during friction on scarified disk - \( M \), \%, that is percentage of seed mass loss after treatment to the seed mass before treatment [10].

The task of investigation is to define the influence degree such parameter as mass loss during the scarification on the sowing quality of seeds, field germination rate, germination energy.

The results of investigations are summarized in table 1.

**Table 1.** Mass loss of sowing material and sowing quality of seed

| Mass loss of sowing material | Laboratory germination, \( \Pi \), \% | Sowing quality of seed | Germination energy, \( E \), \% | Number of broken grain, \( K \), \% |
|-----------------------------|--------------------------------------|------------------------|-------------------------------|-------------------------------|
| 0                           | 43.7                                 | 40.6                   | 0                             |
| 5                           | 49.2                                 | 45.8                   | 0.2                           |
| 10                          | 63.5                                 | 59.1                   | 0.7                           |
| 15                          | 77.1                                 | 69.2                   | 1.3                           |
| 20                          | 93.8                                 | 84.1                   | 2.7                           |
| 25                          | 82.2                                 | 64.8                   | 8.9                           |
| 30                          | 58.1                                 | 52.1                   | 16.6                          |
| 35                          | 42.6                                 | 38.2                   | 27.7                          |
Figure 4. Dependence of sowing qualities of seeds upon mass loss of sowing material: — germination rate \( \Pi \) %, - - - - energy of germination \( E \) %, — the number of broken seeds \( K \) %.

In the results of carried out researches the following mathematical dependences are established:

- dependence of laboratory germination rate (\( y \)) from mass loss of sowing material (\( x \)):

\[
y = -3.4536x^2 + 32.387x + 6.1, \quad (R^2 = 0.83)
\]

(7)

- dependence of germination energy (\( x \)) from mass loss of sowing material (\( y \)):

\[
y = -2.9053x^2 + 26.706x + 10.637, \quad (R^2 = 0.82)
\]

(8)

Mass loss equal to 20\% is considered as optimal from mathematical dependences and constructed diagram herewith the most efficient laboratory germination rate 93.8\% and germination energy 84.1\% are also marked. Further increasing of mass loss of seeds results in damage and reduction of sowing qualities.

Sowing seed qualities of crops are the main characteristics influencing on yield. The germination rate of seeds after sowing, shown in the table 2 is that characteristics of perennial legume grasses.

Table 2. Field germination of perennial grasses seeds, % (on average for 3 years)

| Crop                  | Experiment option |            |
|-----------------------|-------------------|------------|
|                       | without seed scarification | scarified seeds |
| Red clover            | 42.4              | 73.1       |
| Eastern galega        | 41.8              | 72.5       |

In our researches the field germination rate of red clover and eastern galega was increased due to seed scarification carried out during 2-3 days before sowing. At the same time the germination rate of eastern galega seeds was increased by 1.8 and clover seeds - in 1.7.

Increasing of seed germination subsequently affected on increasing of yield and productivity of eastern galega and red clover. Sowing done by scarified seeds differs by greatest plant stand and herbage height.

The dependence of perennial grasses herbage yield from field germination rate of seeds was stronger than on option used scarification and expressed by following correlative-regression equations:

- sowing without seeds scarification:

\[
y = 0.8617x - 38.586, \quad (R^2 = 0.80)
\]

(9)
-sowing with seeds scarification:

\[ y = 0.8641x - 21.518, \quad (R^2 = 0.56) \]  

(10)

The highest herbage productivity was received at option of "eastern galega", sowed with preliminary scarification seeds 28.3 t/ha, that significantly surpassed another options (table3). Essential difference was also observed at option of red clover, sowed with scarified seeds in comparison with control.

Table 3 – Yield and productivity of perennial legume grasses herbage, t/ha

| Option                        | herbage | Dry substance | Digested protein | Feed unit |
|-------------------------------|---------|---------------|-------------------|-----------|
| sowing without seeds scarification | red clover | 18.9          | 4.39              | 2.71      | 0.51     |
|                               | eastern galega | 22.4          | 5.33              | 3.31      | 0.64     |
| sowing with seeds scarification | red clover | 23.1          | 5.31              | 3.28      | 0.61     |
|                               | eastern galega | 28.3          | 6.90              | 4.31      | 0.83     |
| HCPA                          | 2.1     | 0.90          | 0.55              | 0.09      |
| HCPB                          | 3.4     | 0.92          | 0.59              | 0.12      |

Collection of dry substance, digested protein and feed unit was higher in sowing carried out by scarified seeds. It is connected first of all with field germination rate of seeds, consequently, with the greatest plant stand in this sowing.

Production experience confirmed our researches. So, on the farm of Tara district OOO "OPH Frunze" sowing of perennial legume grasses with normal seeds and with scarified seeds were done. Normal seed sowing differed by large infrequency and gave low yield during the first and second years and for the third year the herbage dropped out while the sowing with scarified seeds have been giving steadily high crop yields during six years.

4. Conclusion

1. The highest sowing characteristics are shown under mass loss of sowing material on 20%, germination rate is 93.8%, and germination energy is 84.1%. Increasing of mass loss index of sowing material results in seed damage and reduction of their sowing quality.

2. The highest yield of herbage, the collection of dry substance, digested protein and forage units of perennial legume grasses were obtained during sowing of seeds with their preliminary scarification.

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