Releasing of seeds by a lateral mechanical impact for feeding sesame stems into harvester

Stoyan Ishpekov[1*], Nayden Naydenov[1], Rangel Zaykov[1], Stanislav Stamatov[2], Dechko Ruschev[3]

(1. *Department of Mechanization, Agricultural University, Plovdiv 4000, Bulgaria*;
2. *Institute for Plant and Genetic Resources "K. Malkov", Sadovo 4122, Bulgaria*;
3. *Department of Mechanics, Technical University Sofia, Plovdiv Branch, Plovdiv 4000, Bulgaria*)

Abstract: The objective of the study was determination of the release of seeds, caused by a lateral mechanical impact for feeding sesame stems into harvester in order to define the conditions for reducing losses. An experimental unit for simulating mentioned impact has been created. The percentage of releasing seeds depending on acceleration and the height of application point of the impact on a single stem has been determined. It was found that the feeding of sesame stem into the harvester can be achieved by a lateral impact with acceleration up to 0.5 m s^{-2} and speed up to 1.05 m s^{-1}, if the application point has height 0.6 m from the soil surface. This impact causes up to 5% release of seeds from hybrid 27 when their moisture is 6.2%. The percentages of the seeds releasing of varieties Aida, Nevena and hybrid 23 are also admissible when the applied acceleration is 10.1%, 27.2% and 25.7% less than for hybrid 27 respectively. The lateral feeding of sesame stems into the harvester could reduce losses of seeds shattering up to four times compared with the upper feeding of stems by the conventional reel. The obtained results can be used to proof of a new way and working unit for feeding of sesame stems in the harvester without significant seed losses.

Keywords: sesame seed loses, mechanization

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1 Introduction

The mechanized harvesting of sesame causes significant seed losses depending on many factors of two groups:

- The first group includes the factors associated with susceptibility of sesame plants for releasing seeds during harvest. The most important factors are the degree of maturity, the moisture content and the variety.

- In the second group, the factors characterize the mechanical impact for feeding stems in harvester. These are the direction, application point, speed and acceleration of the impact on stem.

Harvesting of sesame by grain harvesters is accompanied with significant losses of seed, caused by two sources (Trifonov et al., 2013). The grain platform header scatters 20%-22% of the seeds. The thresher causes losses, which are composed of 7%-10% non-threshed seeds and about 50% mechanically damaged seeds.

The losses by the thresher predominate when the seeds moisture is over 10%, but at moisture less than 10% dominate the losses by the header. For sesame threshing at high moisture of seeds has been tested inertial threshing, which does not damage seeds mechanically (Ishpekov et al., 2016). There is no technical solution that satisfies the requirements for seed losses caused by the header (Naydenov et al., 2016). The first scattering causer of seeds is the bat reel. When entering between plants, its bars are wedging between the central stem and branches because of the sharp angle between them. This causes bending and tilting of the stems to soil surface and

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*** Corresponding author: Stoyan Ishpekov**, Agricultural engineering department, Agricultural University Plovdiv 4000, Bulgaria. Email: sishpekov@abv.bg.

releasing of seeds. For solving this problem, low-stem "pygmy" sesame varieties have been created. In their harvesting, the losses of the conventional header reduce to 17% (Langham, 2014).

The second scattering causer of seeds is the cutter bar of the platform header. Before cutting the plants, it shakes them with the working frequency of the cutter bar.

The mentioned reasons for seeds losses by the platform header and the results of prior studies indicate the need for giving proof of a new way of feeding of sesame plants into the harvester (Trifonov et al., 2013; Naydenov et al., 2016). To reduce seed losses, it should meet two important requirements:

- The impact on the plants should not be from the top and be lateral.
- Cutting the stems should be after their inclining over the header.

This way for feeding sesame plants into harvester is also mechanical and requires determination of its parameters.

The objective of the study is determination of the release of seeds, caused by a lateral mechanical impact for feeding sesame stems into harvester in order to define the conditions for reducing losses.

The tasks are:

1. Determining the percentage of the released seeds depending on the acceleration, imparted to a sesame stem and on the height of the application point of the impact at constant moisture of seeds.
2. Determining the percentage of released seeds depending on their moisture at constant impact for feeding stems in harvester.

2 Materials and methods

The study has been conducted with Bulgarian non-dehiscent sesame varieties Aida and Nevena, hybrid 23 and hybrid 27. They open only the top of capsules and the placenta retains seeds up to full maturity (Stamatov and Deshev, 2014). Among the Bulgarian varieties they have the highest values of the index i_3, which indicates that they have the smallest susceptibility for releasing the seeds (Ishpekov et al., 2015).

The release of seeds depending on the factors of the mechanical impact has been measured at three levels of the seed moisture - μ. The first trial was one day after the opening all capsules except the immature seeds on the top of the stem. Subsequent trial was carried out after a significant change of the moisture. The sample is formed of all released seeds and those left in the capsules except the immature from the top of the plant. The sample is formed of all released seeds and those left in the capsules except immature from the top of the stem. The moisture content of seeds was measured by weighing, immediately after the experiment. The influence of the factors from the second group has been determined by mechanical simulation of the impact for feeding sesame stems into the harvester. The percentage of released seed depending on the application point and the acceleration of the impact for inclining a plant has been determined.

The study has been conducted according to experimental design B_2 (Mitkov, 2011) in three replications with the following controllable factors:

- The height from the soil surface - h of the application point of impact on stem.
- The speed - v for inclining stem of single sesame plant. The acceleration - a of inclining stem has been determined by differentiating the electronic signal of speed.

The natural and coded values of controllable factors are presented in Table 1.

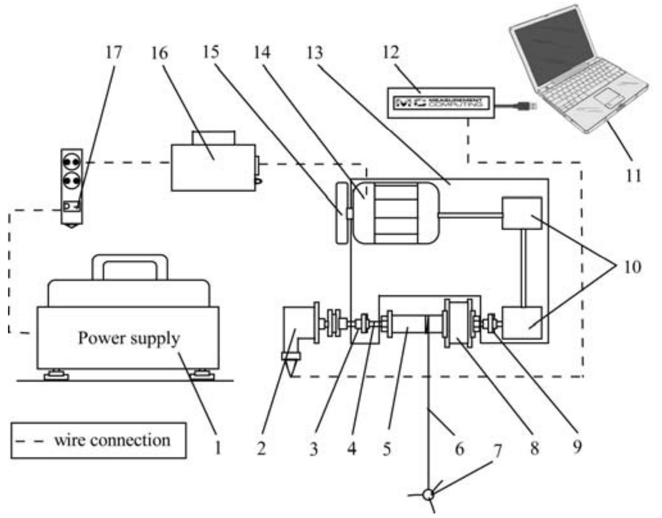
Table 1 Controllable factors

Code	h, m	v, m s^{-1}
–1	0.2	0.31
0	0.4	0.84
+1	0.6	1.30

The response is the percentage of seeds that has been released due to the acceleration of the stem - Da (%). Its determination requires measuring of:

- The percentage of seeds that has been released due to inclining of the stem - Di, (%).
- The percentage of seeds that has been left in the capsules after the mechanical impact - Dc, (%).

A special experimental unit has been developed to simulate the inclining impact on single sesame plant (Figure 1). It consists of mechanical, electrical and electronic systems.



1. Electric generator 2. Incremental encoder (IE) 3, 9. Bearings 4. Shaft 5. Small drum 6. Rope 7. Sesame stem 8. Big drum 10. Worm gears 11. PC 12. Data acquisition module USB-1208HS-2AO 13. Platform 14. Motor 15. Brake 16. Frequency inverter 17. Switch

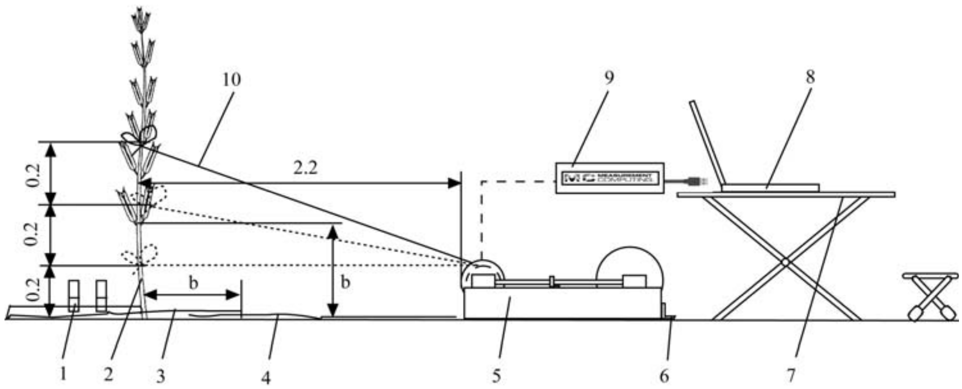
Figure 1 Scheme of the experimental unit for inclining a sesame stem on root

The mechanical system includes a small drum - 5, big drum - 8, worm gears - 10, bearings - 3 and 9, shaft - 4, rope - 6 and brake - 15. This system serves to incline the sesame stem 7 with an assigned speed. It prevents the stem straightening after inclining due to the irreversibility of worm gears.

The electrical system includes electric generator - 1, electric motor - 14, frequency inverter - 16 and a mechanical switch - 17. It serves to generate 220 V for turning the drums 5 and 8 with angular velocity - ω, which ensures achieving the velocity v according to the experimental design (Table 1).

The electronic system is composed of incremental encoder (IE) - 2, PC - 11 and data acquisition module USB-1208HS-2AO - 12 (www.mccdaq.com). This system measures the angle of rotation of drums 5 and 8 by IE - 2 and feds electronic signal into computer 11. The signal is read by a virtual instrument (VI) that has been developed in the environment of software LabView (www.ni.com/labview). Furthermore, VI visualizes and smoothes the signal through splines (Oppenheim at al., 1983) then differentiates it numerically to obtain the angular velocity of the drums ω and the actual speed v of the point of impact. The resultant velocity v also was smoothed and differentiated for getting the acceleration of stem a in the impact point. The angular velocity and diameter of drums has been used for analytical calculation the speed at which the rope 6 inclines stem. These values also serve for evaluating the accuracy of the differentiation and for setting the levels of the factor v according to the experimental design.

For determining of Da, Di and Dc the soil surface alongside of the tested plant has been covered with two sheets of polyethylene as shown in Figure 2. The first sheet - 4 has been spread out in the direction of inclination of the stem. The second sheet - 3 was cut to the middle, allowing its spreading out on both sides of the plant and in a direction opposite to inclination of the stem. The gap of a sheet - 3 has been closed by clamps 1 for catching any falling seeds. The sheet 3 advocated sheet 4 at a distance b, which was equal to the height of the first capsule from the tested plant.



1. Clamps 2. Sesame plant 3. Polyethylene sheet for collecting seed released by accelerating the stem 4. polyethylene sheet for collecting seed released by inclining the stem 5. Drive station 6. Plates for locking the platform 7. Table for operator 8. PC 9. Module USB-1208HS-2AO 10. Rope

Figure 2 Working with the experimental unit

Measurements have been conducted in the following sequence. The electric motor 14 is powered by the generator 1 and through frequency inverter 16 is achieved peripheral velocity v of drum 5 or 8 according the experimental design (Figure 1, Table 1). Then the power switches off by the switch 17 and the rope 10 is tied to the stem of height *h* (Figure 2). Some rope has been left none coiled on drum which length is enough for accelerating the drum to reach assigned speed before pulling of the tested stem.

The operator turns switch 17 on after starting the virtual instrument. The motor 14 accelerates to the preset angular velocity which is measured with an electronic tachometer RS 205-520 (www.rs-electronics.uk). The drum (5 or 8) coils up the rope and then inclines the stem. When the slope of stem to soil surface reaches 45 degree the electric motor switches off and the brake 15 turns on.

As a result of the applied impact the tested stem releases part of its seeds. Sheet 3 collects seeds, leaving the capsules due to the acceleration given to the stem. The sheet 4 catches the seeds, leaving the capsules due to inclination of the stem. The seeds of the two sheets and those left in the capsules are collected in separate paper bags and weighed on electronic scale KERN EMB 200-2 (kern-sohn.com). The mass of the seeds of the three tested plants are weighted and the three percentages *Da*, *Di*, *Dc* have been calculated.

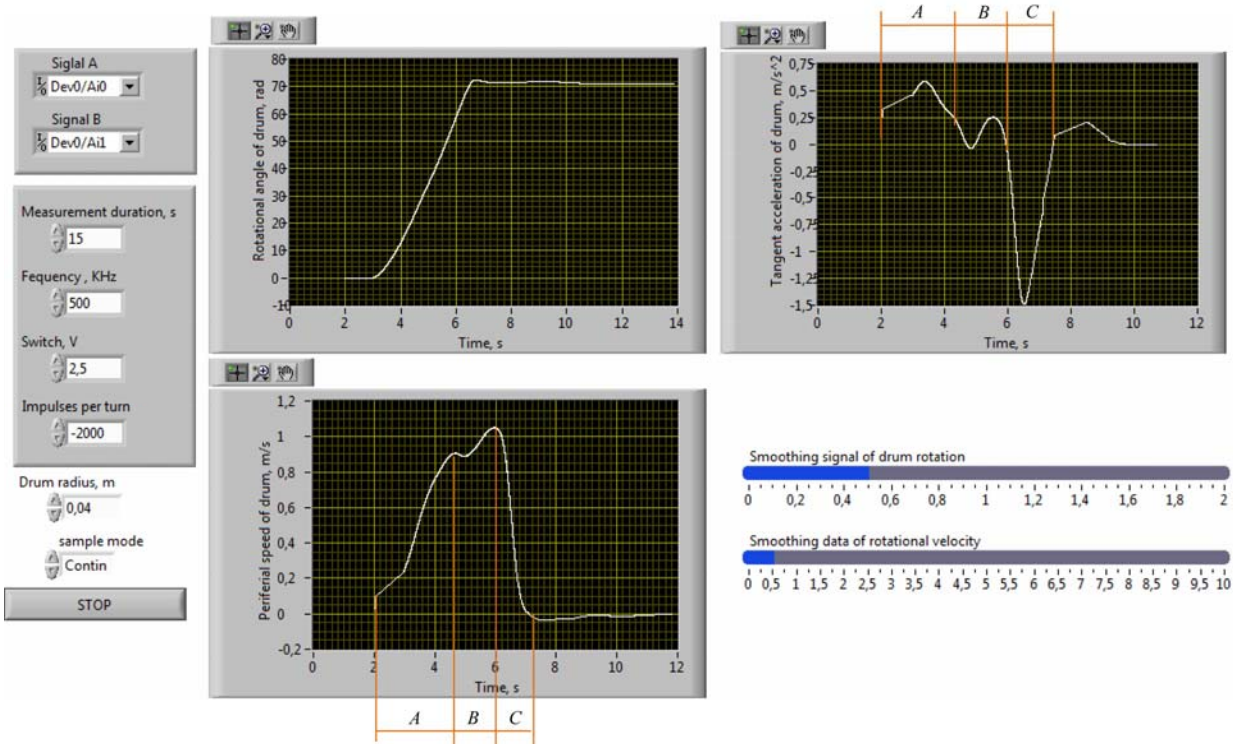
On the front panel of the virtual instrument appear three areas of the speed and the acceleration of the rope, with which the tested stem has been inclined (Figure 3):

A - area of acceleration the rope;

B - area of inclination the stem;

C - area for stopping the rope.

In the area, *A* the drum coils rope with an increasing speed. At the beginning of area *B* the rope pulls the stem and inclines it with speed 0.85 m s^{-1} and acceleration 0.25 m s^{-2}. As a result of the stem reaction, the speed of the rope decreases to 0.84 m s^{-1}. The acceleration decreases to zero, and then reaches again up to 0.25 m s^{-2}. Within a short period the velocity of rope remains constant, then increasing and at the end of area *B* reaches 1.05 m s^{-1}. In the area *C* the drum stops. The most important for the experiment are values of speed and acceleration at the beginning of area *B*, because then the equilibrium of the stem has been broken. At this point the release the seeds from the capsules are the most intensive. Therefore namely those values of speed and acceleration are used for the further analysis.



Note: *A* - area of acceleration of rope; *B* - area of inclination stem; *C* - area for stopping rope.

Figure 3 Front panel of virtual instrument for reading, visualizing and differentiating signal from the incremental encoder

The experiment has been performed in three replications at the experimental fields of IPGR - Sadovo. Experimental data is subjected to regression analysis or curve fitting using the method of least squares at significance level 0.05.

3 Results and discussion

3.1 Released seeds depending on the acceleration and the height of the application point of impact

For the percentage of released seeds *Da* depending on acceleration *a* and the height of the application point *h* at constant moisture of seeds for hybrid 27 has been obtained the following regression Equation (1):

$$D_a = 7.5780 + 19.9195a^2 - 13.0831h \qquad (1)$$

Which with coefficient of determination R^2=0.92 and probability p_F=0.004<0.05.

On Figure 4 is seen that the percentage *Da* decreases linearly with lifting the application point *h*. *Da* grows depending the second power of the acceleration *a*, which is added to the stem at the initial moment of its inclining. The percentage *Da* is below 5% within the area surrounded by a blue dotted line. The area shows combinations of the factors *h* and *a* at which the percentage *Da* satisfies agro-technical requirement for dispersal of seeds caused by the impact for feeding sesame stems into harvester. It is clear that if the application point of impact is at a height *h*=0.2 m, than the admissible acceleration of the stem is $a \le 0.1$ m s^{-2}. If the height increases to *h*=0.6 m, it is admissible acceleration of 0.5 m s^{-2}. For the experimental conditions, this corresponds to the velocity of impact 1.05 m s^{-1}. In practice this means that if the feeding the stems into harvester is done through lateral impact with finger conveyors, then the speed of their chains should exceed with 1.05 m s^{-1} the forward speed of the harvester.

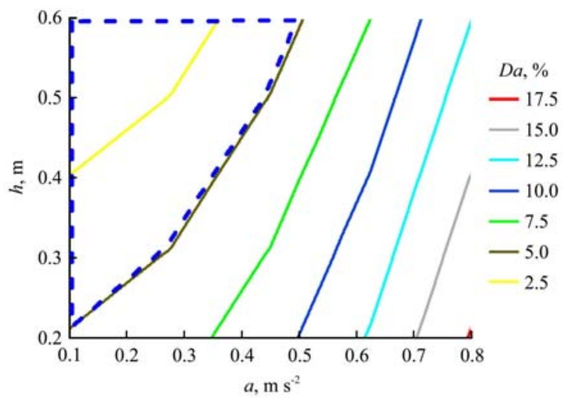


Figure 4 Percentage of released seeds *Da* depending on imparted acceleration and height of the application point of the impact *h* for hybrid 27 when moisture of seed is μ = 6.20%

The nature of alteration of the released seeds *Da* and *Di* depending on the acceleration and the height of the applied point of the impact at the other tested varieties is similar. The admissible accelerations which can be given to stems of other varieties are presented in comparison with those of hybrid 27. The acceleration for Aida must be 10.1% smaller than is acceptable to be given for hybrid 27. For Nevena variety and hybrid 23 the acceleration should be less than 27.2%, and 25.7% respectively.

3.2 Released seeds depending on their moisture at constant impact on feeding stems in harvester

Photos from the experiment are presented in Figure 5. The moisture content of the seeds in the study period is reported in Table 2.

a. Before starting the experimental unit

b. After starting the experimental unit

Figure 5 Photos during the experiment

Table 2 Moisture content of seeds in the study period

	Moisture content μ, %			
	Hybrid 27	Hybrid 23	Aida	Nevena
maximal (initial)	16.6	14.8	16.8	14.8
minimal (final)	6.2	10.5	9.0	7.7

For the percentage of released seeds *Da* caused by the acceleration depending on the moisture of seeds μ at inclining the stem with a speed of 1.05 m s^{-1} and height of applied point *h*=0.2 m have been obtained the following Equations (2) to (5):

For hybrid 27: $D_a = -66341 + 1582571\mu^{-1}$ (2)

with a coefficient of determination R^2=0.96;

For hybrid 23:

$$D_a = -205644 + 3737642\mu^{-1},\ R^2=0.95 \quad (3)$$

For Aida variety:

$$D_a = -133964 + 2731625\mu^{-1},\ R^2=0.96 \quad (4)$$

For Nevena variety:

$$D_a = -208804 + 3568044\mu^{-1},\ R^2=0.94 \quad (5)$$

For the percentage of released seeds *Di* caused by inclining stem depending on moisture of seeds μ under the same conditions has been obtained the following Equations (6) to (9):

For hybrid 27:

$$D_i = -60121 + 1803315\mu^{-1},\ R^2=0.95 \quad (6)$$

For hybrid 23:

$$D_i = -196425 + 3946915\mu^{-1},\ R^2=0.96 \quad (7)$$

For Aida variety:

$$D_i = -126674 + 2943604\mu^{-1},\ R^2=0.96 \quad (8)$$

For Nevena variety:

$$D_i = -175994 + 3754715\mu^{-1},\ R^2=0.95 \quad (9)$$

In analyzing the results takes into consideration the following circumstances:

- The percentage *Di* is determined after has been given the stems an acceleration of 0.50 to 0.56 m s^{-2}, which has caused detachment of seeds from the placenta. Some of the seeds leave capsules at the time of acceleration of the stem. Second part of the seeds leaves capsules after inclining stem, and third part remain in the capsules.

- The study lasted 18 days - from 14.10.2016 to 02.11.2016. During this period the moisture content of seeds falls out differently for the tested varieties (Table 2). This influences for releasing seeds from capsules.

The experimental data are approximated most precisely with reciprocal equations of the first degree. The nature of change of percentages *Da* and *Di* depending on the moisture content of seeds μ is non linear and inversely proportional (Figures 6 and 7). It is seen that the variety Nevena changes *Da* the most rapidly and depending on moisture decrease. Its chart is steeper and means that the optimum time for harvesting this variety is shorter in comparison with other varieties.

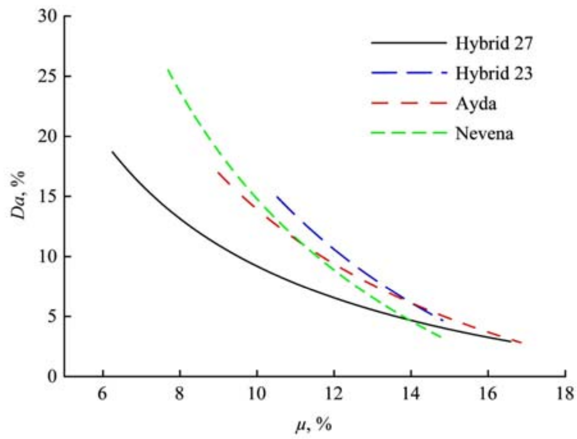


Figure 6 Percentage of released seeds *Da*, caused by accelerating stems, depending on the moisture content μ at inclining stem with speed 1.05 m s^{-1} and 0.2 m height of the application point of the impact

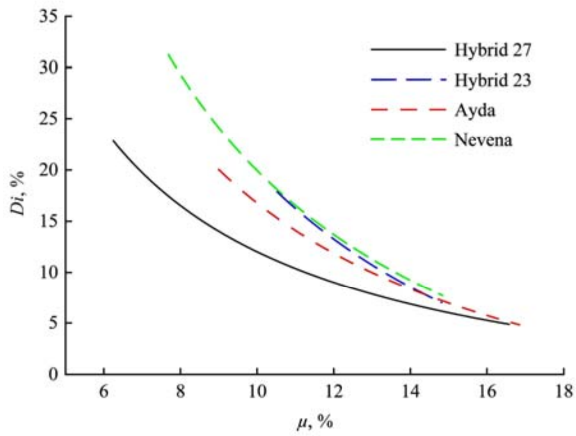


Figure 7 Percentage of released seeds *Di*, caused by inclining stems, depending on the moisture μ at inclining stem with speed 1.05 m s^{-1} and 0.2 m height of the application point of the impact

At beginning of study the moisture content of seeds is greatest for that reason the capsules release very small part of them. For the studied varieties *Da*=2.2÷4.5% and *Di*=5.1÷7.5%. At the end of the study (after 18 days) *Da*=14.7÷25.4% and *Di*=18.6÷31.1%. The percentage *Di* exceeds *Da* at the beginning of the study with 1.40 to 1.49 times, and at the end - from 1.22 to 1.26 times. It is possible the ratio between *Di* and *Da* to be influenced by the circumstance that imparting acceleration causes detachment of some seeds from the placenta, but they leave capsules after inclining the stem.

The minimum percentage *Da* = 2.2% belongs to the hybrid 23 with moisture of seeds μ = 16.5%. The maximum of *Da* = 25.4% shows the variety Nevena, although the moisture of seeds is μ=7.7% and exceeds that of the hybrid 27 (μ=6.2%). The minimum percentage Da = 2.2% belongs to the hybrid 23 with moisture of seeds μ=16.5%. The maximum of Da=25.4% belongs to the variety Nevena, although the moisture of its seeds is μ=7.7% and exceeds that of the hybrid 27 (μ=6.2%).

The smallest values of Di=5.1 ÷ 5.2% have hybrid 27 and variety Aida, whose seeds are with the highest moisture content at the beginning of study. The largest value of Di = 31.1% belongs to the variety Nevena, although the moisture of its seed is not the lowest. From other studies it is known that this variety has one of the smallest index values i_3=0.26, which is indicative of the force with which the seeds are retained by the placenta (Stamatov et al., 2016).

At the end of the study the most seeds remain in capsules of the hybrid 23 (Dc=66.7%) and the variety Aida (Dc=62.9%). It should be reported that their seeds have moisture content 10.5% and 9.0% respectively, while the moisture of the variety Nevena is 7.7% and of hybrid 27 is 6.2% although it was measured simultaneously. These results indicate that the hybrid 23 is best suited for classic threshing among the tested varieties. This finding is confirmed by other studies (Stamatov et al., 2016).

The results show the potential of the lateral feeding of sesame stems in to the harvester. It could reduce losses of seeds shattering up to four times compared with the upper feeding of stems by the reel of conventional header even at the moisture of the seeds 6.2%. Of course, the real potentiality of lateral feeding of sesame stems can be determine after developing and testing of an experimental unit that implements the proposed impact. The results can be used to proof of a new way and working unit for feeding of sesame stems in to harvester without significant scattering of seeds.

4 Conclusions

The moisture content of seeds is very significant but not the only factor that determines the release of seeds from capsules of sesame in technological maturity. The release of seeds also depends on the ability of varieties to hold the seeds in capsules. The feeding of sesame stems in combine harvesting can be achieved by a lateral impact with acceleration to 0.5 m s^{-2} and speed 1.05 m s^{-1}, if the application point is on the height 0.6 m from the soil surface. This impact causes up to 5% releasing of seeds with moisture content 6.20% for hybrid 27. The releasing of seeds of the varieties Aida and Nevena and of hybrid 23 is admissible when for their feeding into the harvester are applied an acceleration, which is less with 10.1%, 27.2% and 25.7% than that for the hybrid 27. The lateral feeding of sesame stems in to the harvester could reduce losses of seeds shattering up to four times compared with the upper feeding of stems by the reel of conventional header.

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