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Indicators of a finger device for feeding sesame stems into harvesting machine

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Abstract

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At the Agricultural University – Plovdiv (Bulgaria) was developed a new device for feeding sesame stems in a harvesting machine. The aim of the study is to determine the main indicators of the device when working with non-dehiscent sesame varieties. The results indicate that the device achieves the minimum seed spillage on the soil surface of 2.5% when the kinematic coefficient of feed chains is 1.33 and the forward speed is 0.63 m/s. The increase of the forward speed from 0.63 m/s to 1.33 m/s leads to grow of device productivity from 1.59 to 3.35 ha/h for each harvested row. Simultaneously, the percentage of spilled seeds of Nevena variety increases with 70%, although the kinematic coefficient remains constant. The device causes 3.4 times less seed spillage than the Wintersteiger spot harvester at harvesting sesame genotype 23 with a seed moisture content of 8.5% and equal kinematic coefficients and forward speeds.

Keywords: sesame; harvesting; mechanisation

Introduction

In many places around the world is carried out active selection for creating sesame varieties with increased resistance of seed scattering caused by the machines and the wind with respect to reduce losses at harvesting. Langham (2014b) has created IND (Improved non-dehiscent) and "Pygmy" sesame varieties, which scatter fewer seeds from the impact of the reel of grain harvester. In Bulgaria have been selected many sesame varieties with placenta attachment, which are also appropriate for mechanical harvesting (Stamatov & Deshev, 2014).

Selection of non-dehiscent sesame varieties gives impetus to research on their mechanized harvesting without significant losses of seeds on soil surface (Stamatov & Deshev, 2014). Investigations began with determination the capabilities of existing harvesting machines (Trifonov et al., 2013; Langham, 2014a). The results obtained indicate that the conventional grain harvester causes significant seed losses which are three types:

– Scattered seeds by the header, which are within 20 ÷ 35%.

– Non-threshed seed – from 7 to 10%.

– Mechanically damaged seeds of the order of 27 to 50%, which are due to their high moisture content at harvesting and mechanical impact of the thresher.

Unsatisfactory results have also been obtained when harvesting sesame with headers for rapeseed, sunflower and soybean (Zareei & Abdollahpour, 2016). Two-phase technologies for mechanized harvesting of sesame also have not produced good results and have shown scattering losses from 20% to 65% (Leffel & Rick, 1988; Naydenov et al., 2016).

At the Agricultural University – Plovdiv (Bulgaria) is carried out research to reduce the mentioned losses by adapting the existing and development of new machines for sesame harvesting. An experimental flow rotational fruit detacher with asymmetric angular vibrations has been developed and patented (Ishpekov et al., 2017). Through inertial way it threshes over 95% of seeds of non-dehiscent sesame varieties Aida and Nevena without damaging them and at fully preservation their germination (Ishpekov et al., 2016). An experimental finger device for feeding sesame stems into harvesting machine has been justified and manufactured (Ishpekov et al., 2017).

The purpose of the study is to determine the main indicators of the experimental device for feeding sesame stems of non-dehiscent varieties into harvesting machine.

The object of the study is the finger device for feeding sesame stems into harvesting machine (Ishpekov et al., in print). It consists of platform 1, drive mechanism (2, 3, 4, 22, 23), two chains 13 with cylindrical fingers 11, two collecting surfaces 25 and rotary disc knife 9 (Fig. 1).

The hydro motor 2 drives the shaft 4, chains 7 and 13 by conical gears. The neighbouring branches of the two chains form a flow that moves in a direction opposite to the forward speed of device. The flow has a trapezoidal shape at the front and in the rear it is a rectangular shape. The ratio between the lengths of the trapezoidal and the rectangular part is changed by positioning the guide rollers 14 relative to the central groove 20 by the plates 10. In this way is also changed the distance from the point of grasping the plant to the point of cutting off the stem as well as its slope at the moment of cutting off. The two collecting plates 25 and the central groove 20 form a collecting trough, the cross-section of which is a trapezoid, oriented with its large base upwards. The distance between lower sides of the cross-section is adjusted by parallel sliding of the plates 25 onto the support plates 27 (Fig. 1 b). The rotary knife consists of a disk to the periphery of which is mounted six trapezoidal rotary blades 9 and a fixed contrary blade 18 which are situated below the platform 1.

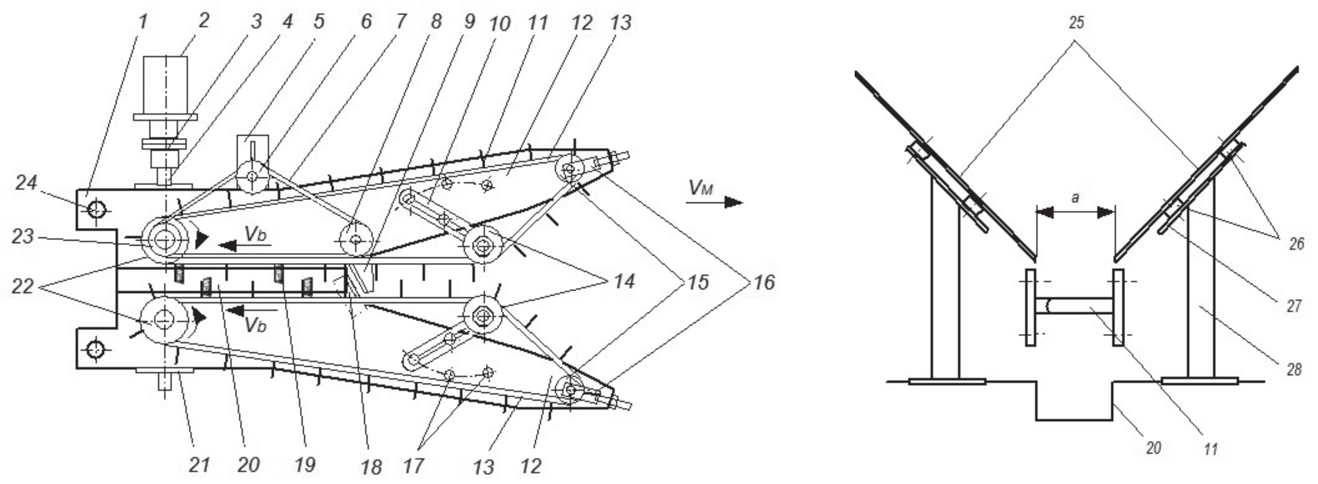
Materials and Methods

The indicators of the developed device are determined by field experiments with Bulgarian non-dehiscent sesame varieties in technological maturity which is most suitable for their mechanized harvesting (Stamatov & Deshev, 2014). The yield and seed moisture content of the variety used is determined by the weighting method immediately before each experiment.

The main quality indicator of the developed device is the percentage of spilled seed on the soil surface, and the most important quantitative indicator is its productivity. Spilled capsules and fell stems on the soil are not observed during the operation of the device and for this reason these losses are not investigated.

The main indicators are influenced by a number of factors from two groups:

(a) Geometric factors including the longitudinal slope of the device, the height of the contact point between finger and plant, the distance from the point of grasping the stem to the point of its cutting off.



a) General scheme **b) Collecting surface**

Fig. 1. Finger device for feeding sesame stems into harvesting machine

1 – platform, *2* – hydro motor, *3* – connector, *4* – shaft, *5* – plate, *6, 8, 15, 22, 23* – chain wheels, *7, 13* – chains, *9* – rotary blade, *10* – adjusting plate, *11* – fingers, *12* – consoles, *14* – guide rollers, *16* – screw tensioners, *17* – fixing hole, *18* – fixed contrary blade, 19 – brushes, *20* – central groove, *21* – flanged bearing bodies, *24* – connection openings, *25* – collecting surface, *26* – beam, *27* – support plate with channel, *28* – stand

(b) Kinematic factors: the forward speed of the machine and the kinematic coefficient of the feeding chains λ

$$\lambda = \frac{v_b}{v_M}, \quad (1)$$

where: v_M is the forward speed of the machine, [m.s^{-1}];

v_b – the speed of the feeding chains (7, 13), [m.s^{-1}].

The distance from the point of grasping to the point of cutting off, along with the kinematic coefficient determine the slope of the stem at the moment of cutting from the root and the place of its falling down. The required longitudinal slope and kinematic coefficient of the feeding chains are theoretically justified under a number of prerequisites (Ishpekov et al., 2019). By a physical experiment, it is confirmed that the longitudinal slope of the feeding chains should be 4 – 6° to minimize the sliding of the finger on the stem during its tilting over collecting surface. The theoretically determined values for the kinematic coefficient of feeding chains are 1.3 – 1.4. However, they are not confirmed by a field experiment, although they are decisive for the operation of the device in real conditions.

When study the effect of kinematic coefficient only the speed of feeding chains is changed from 0.42 to 1.05 m/s, but the forward speed is maintained constant. The kinematic coefficient at which is observed the minimum of spilled seeds is considered to be optimal and is maintained constant in study of the effect of the forward speed of 0.63 to 1.33 m/s. Kinematic coefficient and forward speed are linearly dependent factors and for this reason their influence is examined by two separate single-factor experiments (Mitkov, 2011). The productivity of the developed device is determined by multiplying the forward speed of the machine and the inter-row spacing of the crop.

Field experiments are conducted with an experimental system (Fig. 2) in which the developed device is attached to a tractor 11 via a frame 9. The drive of device is via an elementary hydro drive system, comprising a hydraulic motor 8, a flow regulator 7, the tractor distributor and oil tank.

The shear height of the plants is adjusted through the support wheel 6 and the inclination of the device, which changes by the tractor linkage system. The speed of feed chains 13 is changed with the flow controller 7 and is determined by the rotational frequency of the wheels 22, which is measured by an electronic speedometer. The forward speed is changed through the gearbox of the tractor and is calculated by the time for unfolding the canvas 2 and its length.

Prior each measurement, two polyethylene strips 12 are placed on both sides of the harvested row without shaking the plants (Fig. 2). Each strip has a length of 12 m and a width equal to the row spacing of the culture. On the drum 4 is rolled a canvas 2 with a length of 10 m. Then are adjusted the longitudinal slope of the device, its height above

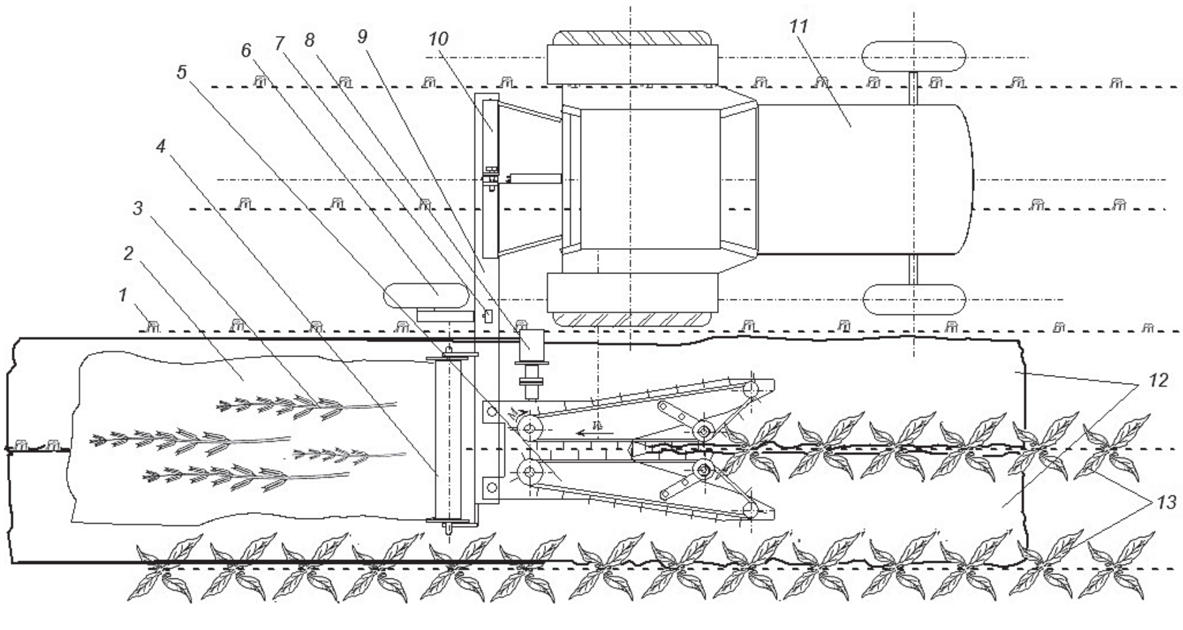


Fig. 2. Scheme of the experimental system

1 – stubble, *2* – canvas, *3* – sesame stems, *4* – drum, *5* – developed device, *6* – supporting wheel, *7* – flow regulator, *8* – hydraulic motor, *9* – frame, *10* – linkage system, *11* – tractor, *12* – polyethylene strips, *13* – sesame plants the ground, the speeds of the chains and of the machine. The free end of the canvas is stabilized to the soil surface.

After starting, the tractor moves at a forward speed of $v_м$ and the chain speed is v_b. When $v_b > v_м$, the fingers grasp the plants and tilt them over the device and later the knife cuts off stems. They fall on the collecting surface and glide back under impact of the fingers until lie down on the canvas 2. Part of the seeds leave capsules as a result of mechanical effects at tilting and cutting off stems and fall also on the collecting surface. After that they slide into the central groove and are moved to the canvas by the brushes.

After each trial is determined the mass of the seeds spilled on the polyethylene strips and is calculated the losses of scattering by the formula:

$$P_L = 100\frac{L}{Y}, \quad (2)$$

where: P_L is the percentage of spilled seed on the soil surface, [%];

L – the mass of the seeds spilled on the polyethylene strips, [g];

Y – the yield of plants harvested by the device for one trial, [g].

$$Y = Y_1 N_p, \quad (3)$$

where Y_1 – the average biological yield of one plant, [g];

N_p – the number of plants harvested by the device for one trial.

Experimental data are subjected to regression analysis at significance level of $a = 0.05$.

The percentage of spilled seed is influenced by working conditions and for this reason this indicator is determined also at parallel operation of the developed device and of the combine harvester when harvesting one sesame variety. Prior to parallel experiment, the same polyethylene strips are placed between the rows of plants that are processed by the grain harvester. Both machines move one after the other at equal forward speeds. The kinematic coefficients of the combine reel and of the feeding chains of the device are also equal. The percentage of spilled seed by the grain harvester is determined also by formula (2).

Results and Discussion

The parameters of the device are determined in the experimental fields of Institute of Plants and Genetic Recourses "K. Malkov", town of Sadovo (Fig. 3). The experiments are conducted with Bulgarian non-dehiscent sesame varieties Aida, Nevena and hybrid 23, which have been selected in the same institute (Georgiev et al., 2014).

Fig. 3. The developed device during the study

The influence of kinematic coefficient on the percentage of spilled seed by the device has been determined with Aida variety at 9.7% seed moisture content. The obtained regression equation is:

$$P_L = 126.8901 - 171.6734.\lambda + 59.625.\ \lambda^2 \quad (4)$$

with determination coefficient $R^2 = 0.95$, Fisher's Criterion $F = 9.8259$ and probability $p_F = 0.0128$. The percentage of spilled seed on the soil surface is the smallest when the kinematic coefficient of the device is in the range $l = 1.2 – 1.6$ (Fig. 4). The experimental minimum of spilled seeds P_L = 2.5% has been obtained at $l = 1.33$. In this case, the fingers tilt stems above the collecting surface fluently. The increasing of

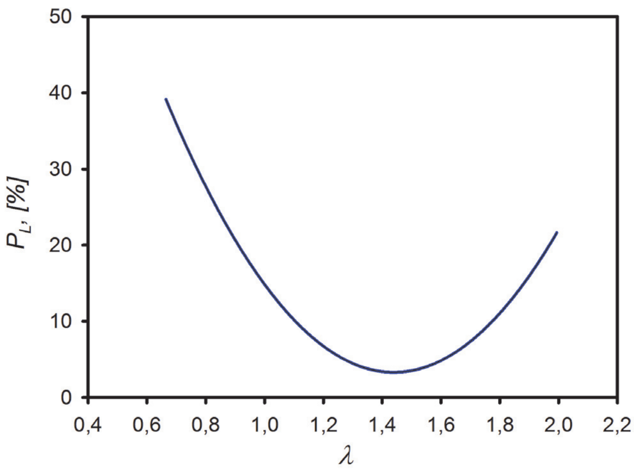


Fig. 4. The percentage of spilled seed with 9.7% moisture content of Aida variety depending on kinematic coefficient of the device at forward speed 0.63 m/s

the coefficient above 1.8 leads to growing up the percentage of spilled seeds more than 12% due to the sharp grasping and tilting of stems. This is accompanied by several bending of the stems, which causes seed scattering in all directions and thereby some of them do not fall on the collecting surface. At $l < 1$ the percentage of spilled seeds reaches 40% due to changing the nature of impact on stems. The fingers tilt them in direction of forward speed and at $l < 0.7$ the influence is accompanied by a shock which causes intensive seed scattering on the soil surface. The results obtained for the kinematic coefficient are fully confirmed with the theoretical studies of the device (Ishpekov et al., 2019).

The influence of forward speed on the percentage of spilled seed from the device was determined with Nevena variety at seed moisture content of 8.5% and at $l = 1.33$.

The obtained regression equation is

$$P_L = -2.9011 + 26{,}3825.v_M - 8{,}3981.v^2_M \quad (4)$$

with determination coefficient $R^2 = 0.97$, Fisher's Criterion $F = 0.29$ and probability $p_F = 0.002$.

The percentage of spilled seeds grows up with increasing of forward speed, although the kinematic coefficient is maintained constant (Fig. 5). Apparently, growing up the speed of feed chains leads to increase in the acceleration of stems tilting.

The developed device can feed stems into harvester at a forward speed of 0.63 m/s to 1.33 m/s, which corresponds to a productivity of 1.59 to 3.35 ha/h at harvesting a single row. When the developed device is a part of a header, then its performance is obtained by multiplying the mentioned figures by the number of simultaneous harvested rows by the combine harvester. The growing up the speed and respectively the productivity of device at feeding stems of Nevena variety leads to increasing seed losses up to 70%.

The parallel study was performed with the genotype 23 at seed moisture content of 8.9%. It has been determined the percentage of spilled seed from the developed device and from a Wintersteiger grain harvester at a forward speed v_M = 1.33 *m/s* for both machines (Fig. 6). The kinematic coefficients of the harvester reel and of the feeding chains of the device are equal to 1.33. Under these conditions, the developed device scatters 8.8% from the yield and the Wintersteiger harvester 30.2%, which is a difference of 3.4 times (Fig. 7).

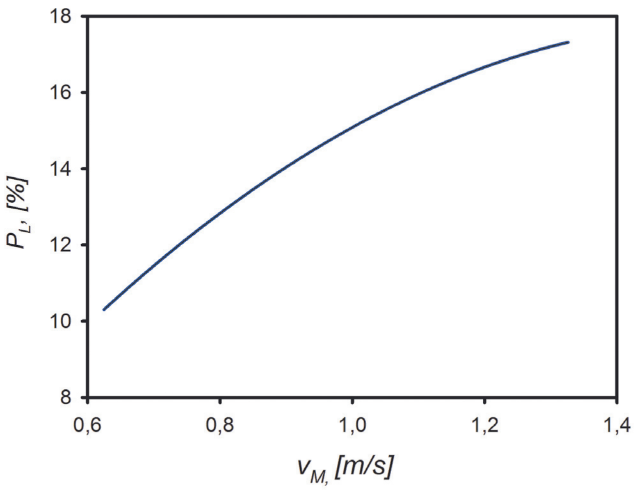


Fig. 5. The percentage of spilled seed with 8.5% moisture content of Nevena variety depending on forward speed and at kinematic coefficient *l* = 1.33

Fig. 6. Parallel determination of seed losses from grain harvester Wintersteiger and the developed device

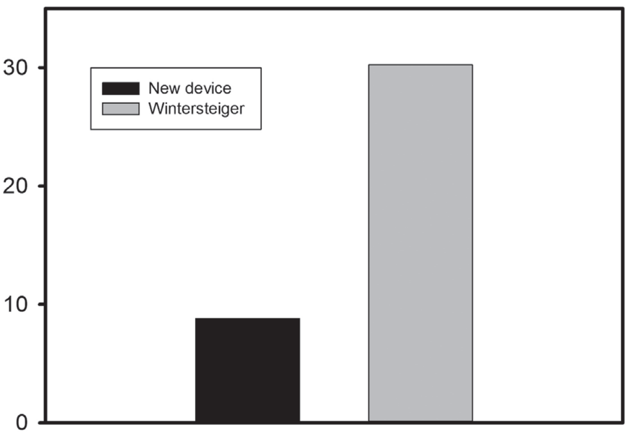


Fig. 7. Percentage of spilled seed of genotype 23 with moisture content of 8.9% caused by the developed device and by the grain harvester Wintersteiger at a forward speed of 1.33 m/s

Significantly greater losses by the combine harvester are rooted in the inappropriate impact of its reel and the cutting apparatus on the sesame plants (Langham, 2014 b; Naydenov et al., 2016). The reel wedges in the boxes and branches as a result of which it bends the stems to the soil surface. The cutter bar shakes the stems several times before cutting them off the root.

Figures 4 and 5 also show the effect of the variety on seed losses. In the working mode with the optimal kinematic coefficient $\lambda = 1.33$ and the minimum velocity $v_M = 0.63$ *m/s*, the device scatters 2.5% of the Aida yield and 10.3% of the Nevena. In the mode of parallel study, the developed device scattered 15.7% of Nevena yield and 8.8% of the genotype 23, although the moisture content of their seeds did not differ significantly.

The experimental data obtained are well suited to the results from other studies and show once again the strong effect of the variety and its degree of maturity on losses at mechanized harvesting of sesame (Georgiev, 2014). On the other hand, these results indicate that the device should feed the stems of various sesame varieties under different kinematic modes.

The results obtained can be used to design and adjust the developed device when working with different sesame varieties and field conditions.

Conclusions

There is developed and examined device for feeding sesame stems to harvesting machine that achieves the minimum percentage of scattered seeds on the soil surface of 2.5% in working mode with kinematic coefficient of 1.33 and forward speed 0.63 m/s.

The growing up of the forward speed from 0.63 m/s to 1.33 m/s increases device productivity from 1.59 to 3.35 ha/h for each harvested row, whereby the percentage of spilled seeds of Nevena variety grows up to 70 %, although the kinematic coefficient remains constant.

The device causes 3.4 times less seed spillage than the spot harvester Wintersteiger at harvesting sesame genotype 23 with a seed moisture content of 8.5% and equal kinematic coefficients and forward speeds.

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