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Seed passage speed through short vertical delivery tubes at precise seeding

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Abstract. The development trend of precision seed machines is the use of central seed hopper. Another requirement is to increase the driving speed during precise sowing up to 10–12 km h^{-1}. This involves increased demand for uniformity of the seeds movement between the dosing mechanism and seed coulters. Previous measurements of seed passage speed showed undesirable changes in distance of seed during passage by long delivery tubes. The research was therefore focused on the evaluation of flyby seed parameters in short vertical delivery tubes of inner diameter 10, 12 and 14 mm and a length of 0.50 m. The aim of the experiment was to evaluate the dependence of the seed passage speed of corn, winter wheat and oilseed rape on the air pressure in the supply hose from the fan to short vertical delivery tubes and to recommend appropriate settings of air pressure in the intake air to delivery tubes. Logarithmic function was chosen for the description of dependence of flyby speed of three crops seeds on air pressure in the vertical tubes. The speed of the seed at the end of seed tubes, established as necessary for high-speed seeding (10 m s^{-1}) was achieved in all three test seed tubes when the air pressure in the supply pipe 3.0 kPa. Air speed in the vertical delivery tubes was 3.15 to 4.2 times higher than the speed of the seeds. Based on the correlation index values from 0.90 to 0.96, the high quality of the regression model was found in all cases. It was found that the short vertical delivery tubes of internal diameter 10, 12 and 14 mm are useful for a new developed seeder. On the other hand, deviations of seed passage speed for winter wheat seeds occur at higher air speed. Higher internal diameter of downtube decreased significantly seed passage speed for maize seeds.

Key words: precise seeding, flyby speed of seeds, short vertical delivery tubes.

INTRODUCTION

Individual seed hoppers for every sowing unit are still used for precision sowing machines. Seeds fall from a low height from the metering unit directly into a furrow which is produced by furrow opener. Recently, producers of seeders and precision seeders are focused on the development of machines with the application of a central hopper for seeds. The metering units for precise sowing are located above the furrow opener. Pneumatic transport of the seeds in the seed tubes is an important requirement for correct operation of machines for accurate sowing which is called high-speed seeding (precise sowing with ground speeds from 10 to 12 km h^{-1}). The seeds must be transported by the air stream in the tube at regular distances. There is also a requirement that the minimum differences would be in speed between the individual seeds for various crops. Previous measurements of seed passage speed showed undesirable changes in distance of seed during passage by long delivery tubes. According to Cui & Grace (2006), further work is needed to improve understanding of multiphase biomass pneumatic conveying and to assist in the development of biomass energy and conversion processes. Pneumatic conveying, in which particles are transported or suspended by gas (air) in vertical and horizontal conveying systems, has found wide industrial applications. Other information for studying of pneumatic conveying are in the works of Russo (2011) and Jech et al. (2011).

The physical characteristics of seeds can strongly influence their movements in the agricultural machine as well as in the air. The knowledge of the physical characteristics of particles is essential for the constructors and operators. In this respect the size, size distribution, shape, mass, bulk density, true density, coefficient of friction and aerodynamic resistance of grains are great importance (Polyak & Csizmazia, 2010).

The aim of measuring of the vertical seed flyby in delivery tubes was to determine the effect of different air pressure in the supply hose on the speed of crops seed in three short vertical downtube with different inner diameters.

MATERIALS AND METHODS

Vertical delivery tubes 0.50 m length were connected to the outlet of a fan used in FARMET Excelent seed seeders. The fan was driven by Rexroth hydrogenerator with a fluent change the rotation frequency of the fan rotor – Bosch Rexroth type ABKAG-60AL09-A10VSO-28/160M058F652. Changing the speed of the fan rotor was used to adjust the air pressure in the supply hose from the fan to vertical delivery tubes.

To measure the airstream speed in delivery tubes were used two devices: a TESTO pressure probe, 0638.1445 model connected to a TESTO 445 device with internal memory. Pressure probes were connected to Pitot tubes to measure differential pressure and airstream speed in the axis of delivery tubes (Flandro et al., 2012). Pitot tubes were installed in delivery tubes at a distance of 0.05 m in front of the end of vertical delivery tubes.

The airstream speed in vertical delivery tubes of 10, 12 and 14 mm in inside diameter and of the lengths 0.50 m was measured at a pressure in the supply hose from the fan to delivery tubes in steps of 0.5 kPa, in the range from 0.5 to 4.0 kPa (Table 1). To measure seed passage speed BALLUFF optical sensors, BLG 30C-005-S4 model, connected to a datalogger, were used. Optical sensors were from each other at a distance of 0.10 m. The bottom optical sensor was placed at a distance of 0.05 m from the ends of the tube. The speed of seed passage was calculated from the measured time segments. Each measurement at a increasing air pressure in steps of 0.5 kPa were done in ten replications. Information about crops are in Table 2. Seed passage speed of these three crops was measured: corn, winter wheat and winter oilseed rape. Besides the size these seeds differ in shape – oilseed rape is rounded, wheat and maize have three different dimensions.

The reason for the selection of seed tubes with an inner diameter 10, 12 and 14 mm were the results of previous measurements of seed flyby in tubes with internal diameter 16 mm. Basic data about the selected seed crops are presented in Table 2.

The results of measurements were processed using Statistica 12 (StatSoft, Inc., Tulsa, Oklahoma) program.

Table 1. Air velocity in the vertical delivery downtubes with different air pressure in the supply tube

Air pressure in supply tube [kPa]	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
The rotation speed of the fan rotor [1 min^{-1}]	1,305	1,824	2,150	2,543	2,815	3,066	3,305	3,500
Air velocity on delivery tube inner diameter 10 mm (m s^{-1})	18.15	24.37	25.53	27.70	28.48	34.97	*	*
Air velocity on delivery tube inner diameter 12 mm (m s^{-1})	17.94	23.40	29.04	34.82	38.51	43.31	47.72	*
Air velocity on delivery tube inner diameter 14 mm (m s^{-1})	17.32	23.37	30.21	30.55	31.49	44.83	48.97	*

* – out of the measuring range.

Table 2. Crops, varieties and thousand seeds weight

Crop	Variety name	Thousand seeds weight (g)
Corn (*Zea mays* L.)	CE 220 H	312.5
Winter wheat (*Triticum aestivum* L.)	Darwin	45.6
Winter rape (*Brassica napus* L. *var. napus*)	Hornet	5.6

RESULTS AND DISCUSSION

The graph in Fig. 1 shows the flyby speed of maize seed in vertical downtube with internal diameter 10, 12 and 14 mm at increasing air pressure in the supply tube. Logarithmic function was used for the description of dependence of flyby speed of corn seeds on air pressure in the vertical tubes.

The highest flyby speed of seed was always observed at the highest pressure setting, a 4 kPa. For maize seed with a decreasing inner diameter seed pipes speed flyby of seed corn grew. The differences are increased with increasing pressure within the air supply tube. For corn seed flyby speed of seed grew with a decreasing of inner diameter of delivery tube. During the seeder work it is appropriate to maintain the rotor speed of the fan at a level close to 3,000 1 min^{-1}. This value corresponds to the pressure of 3 kPa in the supply tube from the fan to delivery tubes. When air pressure exceeds 3 kPa flyby speed of seed exceeds 10 m s^{-1}, which is sufficient for reliable transport of maize seed in the short vertical tubes. Delivery tubes with inside diameter 10 and 12 mm have proved to be suitable for corn seed.

The graph in Fig. 2 shows the flyby speed of winter wheat seed in vertical downtube with internal diameter 10, 12 and 14 mm at increasing air pressure in the supply tube. Logarithmic function was also used for the description of dependence of flyby speed of winter wheat seeds on air pressure in the vertical tubes. When the air pressure in the supply hose from the fan to delivery tubes is between 1 to 3 kPa there were not statistical significant differences between the values of flyby speed. Only two values of flyby speed for highest air pressure and inner diameter of tube 12 mm showed differences.

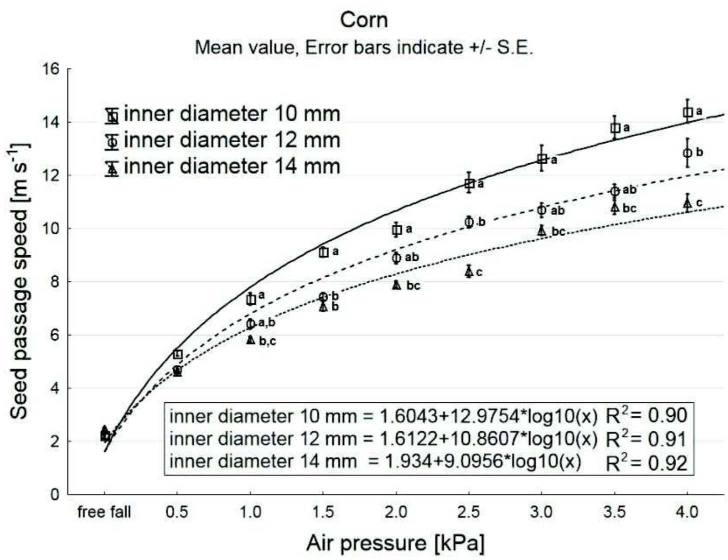

Figure 1. The flyby speed of maize seed in vertical downtube with internal diameter 10, 12 and 14 mm at increasing air pressure in the supply tube. Significant differences are indicated by different letters (a, b, c).

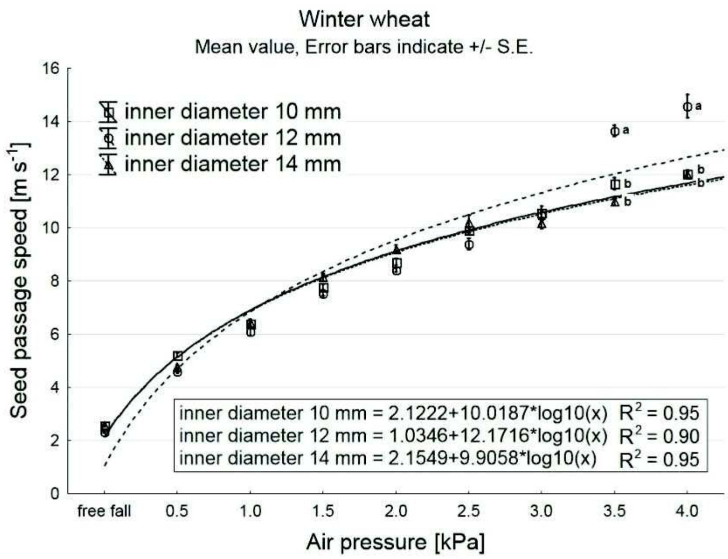

Figure 2. The flyby speed of winter wheat seed in vertical downtube with internal diameter 10, 12 and 14 mm at increasing air pressure in the supply tube. Significant differences are indicated by different letters (a, b).

There were not found statistically significant differences in the flyby speed of oilseed rape seeds (graph in Fig. 3) for delivery tube with an inner diameter of 10 and 14 mm and pressure in the range 2–4 kPa. Statistically significant differences showed values for tube with inner diameter 12 mm.

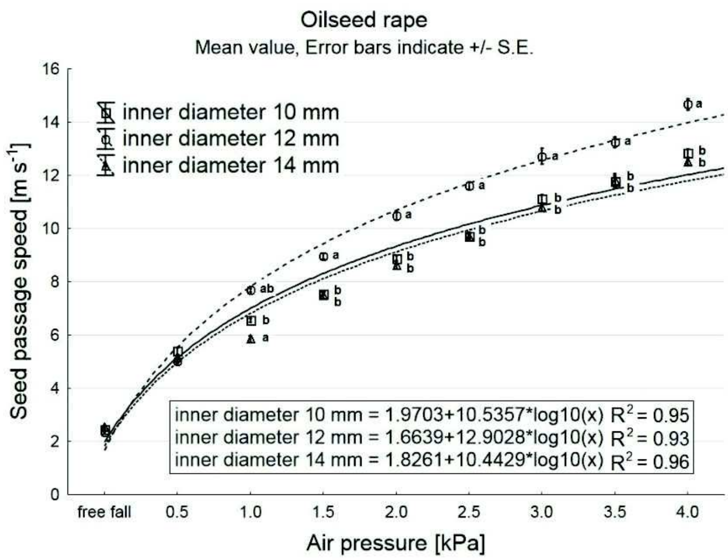

Figure 3. The flyby speed of oilseed rape seed in vertical downtube with internal diameter 10, 12 and 14 mm at increasing air pressure in the supply tube. Significant differences are indicated by different letters (a, b).

Comparison of values of flyby speed between the different seeds and inner diameter of delivery offers graphs in Figs 4, 5 and 6.

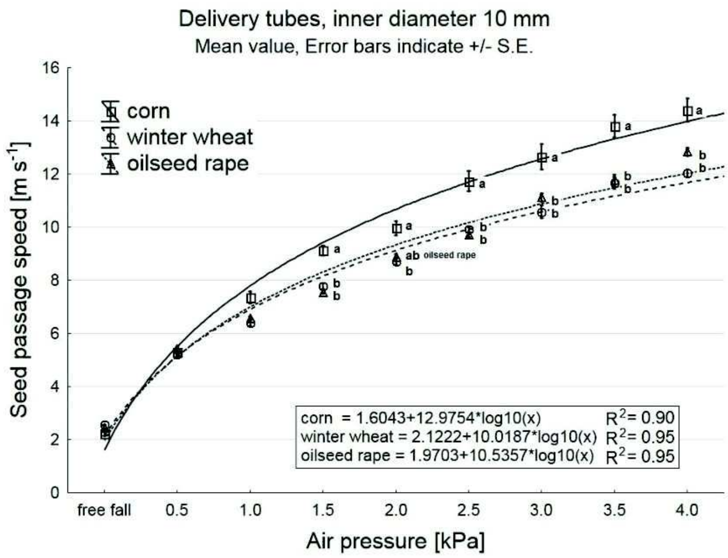

Figure 4. The flyby speed of seeds in vertical downtube with internal diameter 10 mm at increasing air pressure in the supply tube. Significant differences are indicated by different letters (a, b).

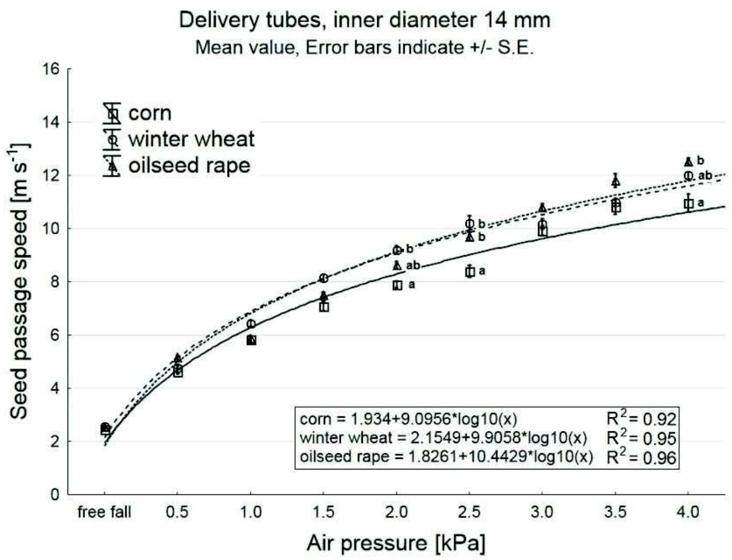

Figure 5. The flyby speed of seeds in vertical downtube with internal diameter 14 mm at increasing air pressure in the supply tube. Significant differences are indicated by different letters (a, b).

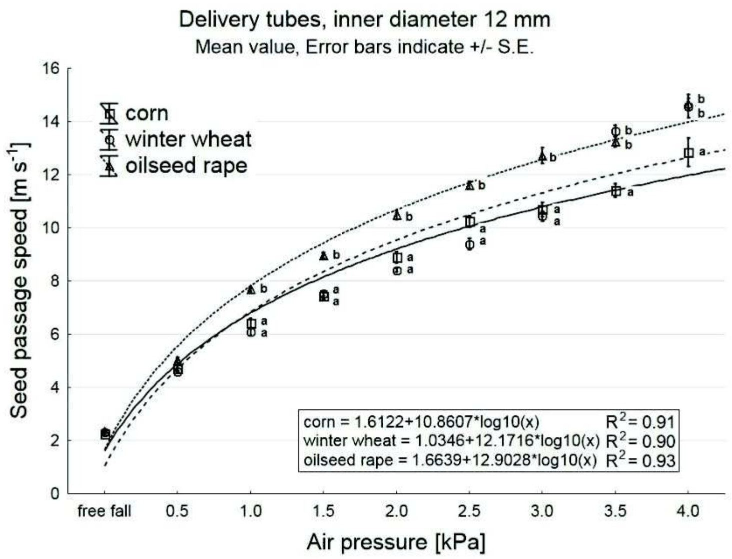

Figure 6. The flyby speed of seeds in vertical downtube with internal diameter 12 mm at increasing air pressure in the supply tube. Significant differences are indicated by different letters (a, b).

The graph at Fig. 4 shows that there are not significant differences in the flyby speed for inner diameter 10 mm for the seeds of rape and winter wheat. Maize seed showed a higher speed for values of air pressure higher than 1.5 kPa. Similar character of speed flyby was observed for wheat and oilseed rape with an internal diameter of tube 14 mm – see the graph on Fig. 5. Speed flyby of corn seed was found lower than for the wheat and rape seeds at an air pressure of 3 kPa. Other differences in the speed flyby for three crops were found in case of tube with an inner diameter of 12 mm – Fig. 6. Similar values of flyby speed of seeds were observed for maize and oilseed rape. Seeds of oilseed rape has significantly higher flyby speed.

There were not statistical differences for free fall. The values were between 2.21 to 2.57 m s^{-1}. This low flyby speed of seed in vertical delivery tube is not suitable for high-speed seeding. Based on the requirement for the seeding speed higher than 10 m s^{-1} and for better fixation of seeds in a row, the higher flyby speed of the seeds in the delivery tubes is necessary. The minimum required flyby speed of seed was achieved with the pressure 3.0 kPa in the supply tube. The flyby speed of seeds has not been measured if the air pressure in the supply tube was higher than 4 kPa, because of the risk of seeds damage was assumed. Ghafori et al. (2011) states that mechanical damage of seeds increased linearly as the air velocity increased.

The problem of high speed precision seeding is in the fact that the seeds of wheat and maize have three different dimensions: length, width and thickness. This causes irregularity in movement of these seeds during their aerial drift. There are applied the rules of aerodynamics (Caughey, 2011).

The results are in accordance with the requirements of high seeding performance in compliance with the required seeding (Kruse et al., 2008). High-speed precision seeding is a perspective to the verification of new ways of stand establishment of crops, which are used in soil conservation technologies (Götz & Bernhard, 2010).

CONCLUSIONS

After the experience with larger inner diameter delivery tube it has proved as necessary to verify the flyby seeds of selected crops seeds in vertical delivery tubes with smaller inner diameter. Air pressure in the supply tube was chosen as an indicator for setting of the seeder for pneumatic transport of seed in the delivery tubes. The air pressure is easily adjustable and easy to check by the driver and operator of the seeder.

Previous experiment with the flyby of the seeds in vertical delivery tube has shown that the risk of blockage delivery tube increases when delivery tube with inner diameter less than 10 mm was used.

For delivery tubes with internal diameter of 16 mm or more were found that the irregular movement of the seed increased and accuracy of seeding decreased. The results presented in this paper demonstrate the applicability of the short vertical delivery tubes with internal diameter of 10 to 14 mm for a new machine for precision seeding.

REFERENCES

Caughey, D.A. 2011. *Introduction to aircraft stability and control course*. Notes for M&AE 5070. New York, Cornell University Ithaca, 154 pp.

Cui, H. & Grace, J.R. 2006. Pneumatic conveying of biomass particles: a review. *China Particuology* **4**(3–4), 183–188.

Ghafori, H., Hemmat, A., Borghaee, A.M. & Minaei, S. 2011. Physical properties and conveying characteristics of corn and barley seeds using a suction-type pneumatic conveying system. *African Journal of Agricultural Research* **27**(6), 5972–5977.

Götz, S. & Bernhard, H. 2010. Production comparison of new sowing methods and normal seed of silage maize. *Landtechnik* **2**, 107–110. (in German).
Flandro, G.A., McMahon, H.M. & Roach, R.L. 2012. *Basic aerodynamics*. Cambridge: University Press. 419 pp.
Jech, J., Angelovičová, M., Angelovič, M., Berkášek, K., Honzík, I., Kvíz, Z., Mareček J., Krnáčová, E., Polák, P., Poničan, J., Rybka, A., Ružbarský, J., Sloboba, A., Sosnowski, S., Sypula, M. & Žitňák, M. 2011. *Machines for plant production* **3**. Praha, Profi Press, 368 pp. (in Slovak).
Kruse, M., Hackländer, J., Humpisch, G., Lamprecht, H., Pippel, G. & Schwanz, H. 2008. *Seeds and seeding manual*. Agrimedia GmbH, 214 pp. (in German).
Polyak, N.I. & Csizmazia, Z. 2010. Measuring the Terminal Velocity of Particles with an Elutriator, Using Image Analysis. In: *CIGR Workshop on Image Analysis in Agriculture*, 26–27. August 2010, Budapest.
Russo, G.P. 2011. *Aerodynamic measurements*. Cambridge, Woodhead Publishing, 257 pp.