# EXPERIMENTAL STUDY OF PRECISION SEEDING METERING SYSTEM SEED FALL RATE

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**Abstract.** Enhancing the resilience of agricultural production to climate change, while simultaneously increasing resource-use efficiency, demands sowing technologies that are versatile and compatible with precision agriculture. Research and development of seed metering mechanisms play a critical role in achieving uniform seed placement, appropriate plant spacing, and improved crop performance. An effective metering system limits mechanical damage to seeds, minimizes losses, and enhances overall sowing efficiency. Although mechanical seed metering devices are fundamental components of precision planters, systematic investigations into their performance remain insufficient. This research gap restricts progress in improving seed distribution accuracy and adversely affects crop establishment and productivity across varying operating conditions. To address this issue, experiments were carried out using a specially designed laboratory test stand. Performance evaluation focused on parameters such as seed discharge frequency and seed interval, defined as the elapsed time between successive seeds leaving the hopper. Seed motion at the outlet was captured using a high-speed camera, enabling precise analysis of seed spacing. Each experiment was conducted in triplicate to ensure the reliability and repeatability of the results. Findings demonstrated that seed falling velocity and the temporal spacing between successive seeds were strongly affected by the disk rotational speed, and the reduction in standard error at higher speeds indicated improved seed flow stability and distribution uniformity. The results also confirmed that the developed seeder test bench is a simple, practical, and reliable tool for accurately evaluating seed metering performance as an alternative to conventional methods.

**Keywords:** seeder, metering system, seeds, precise seed spacing, seeder test bench.

## Introduction

Modern agricultural production increasingly integrates advanced technologies aimed at improving efficiency, productivity, and sustainability. Within crop production systems, the sowing operation is one of the most critical stages because the spatial arrangement of plants established during seeding strongly influences crop development and final yield. Precision agriculture technologies seek to optimize this process by ensuring that seeds are placed in the soil at predetermined distances and depths, enabling uniform crop emergence and efficient use of field resources [1].

One of the key components determining the success of precision sowing is the seed metering system integrated into the seeding machinery. This mechanism regulates the delivery of seeds from the hopper to the soil and must ensure that seeds are released individually and consistently during operation. If the metering process is not properly controlled, problems such as multiple seed drops or missed seed placements may occur, leading to irregular plant distribution and reduced crop performance. Therefore, the design and functionality of seed metering devices are crucial factors affecting the overall performance of precision planting equipment [1].

Various engineering solutions have been developed to achieve accurate seed delivery. Traditional seed metering systems are mainly based on mechanical principles and include mechanisms such as inclined plate, finger pickup, or spoon-type devices. In more advanced systems, pneumatic technology is used to improve seed selection and placement by utilizing airflow to control seed movement. Each of these mechanisms has specific advantages and limitations, and their effectiveness depends on factors such as seed characteristics, machine speed, and field conditions.

Uniform seed spacing within the row is particularly important for achieving optimal crop growth. When seeds are distributed evenly, competition between plants for nutrients, water, and sunlight is reduced, which contributes to improved plant development and higher yield potential. However, maintaining consistent seed spacing during field operations can be challenging. Agricultural machinery often operates under variable conditions, where uneven terrain and fluctuations in forward speed may negatively influence the accuracy of seed placement. As a result, seed metering systems must be capable of maintaining precise seed discharge even when operating conditions change [2].

In recent years, significant attention has been given to improving the performance of precision seeding equipment through the development of advanced control systems, improved metering mechanisms, and higher operational speeds. Despite these technological advancements, many newly developed precision seeding systems still require extensive testing and evaluation before they can be widely adopted in practical agricultural applications. Research studies have indicated that further experimental investigations are necessary to better understand the behaviour of seed metering devices and to improve their operational stability and reliability [3].

For this reason, experimental analysis of seed metering mechanisms plays an important role in the development of modern precision seeding technology. Investigating the operational characteristics of these systems allows researchers to evaluate parameters such as seed spacing accuracy, seed delivery consistency, and overall system stability. The results obtained from such studies can be used to optimize machine design and improve the performance of agricultural machinery used in precision planting.

The main objective of this study is to experimentally investigate the performance of a mechanical seed metering system developed for precision agriculture applications, with particular emphasis on evaluating seed falling velocity and seed flow characteristics, which directly influence seed distribution uniformity in the furrow, by using a newly developed, simpler, and more practical seeder test bench.

## Materials and methods

Experimental tests were carried out using a specially designed test bench. The bench consisted of a seed metering mechanism, a speed controller, a Microstep Drive DC: 9-40 VDC, an HDR-60-24 electric motor, and a mass measurement system. The dimensions of the seed metering mechanism were selected using a modelling method presented in the study [4]. The overall view of the test bench is shown in Fig. 1a. A specially designed seed pickup disc with 14 spoon units was used (Fig. 1b). The disc dimensions were also presented and justified in [4]. The disc was manufactured using a 3D printer with PLA material.

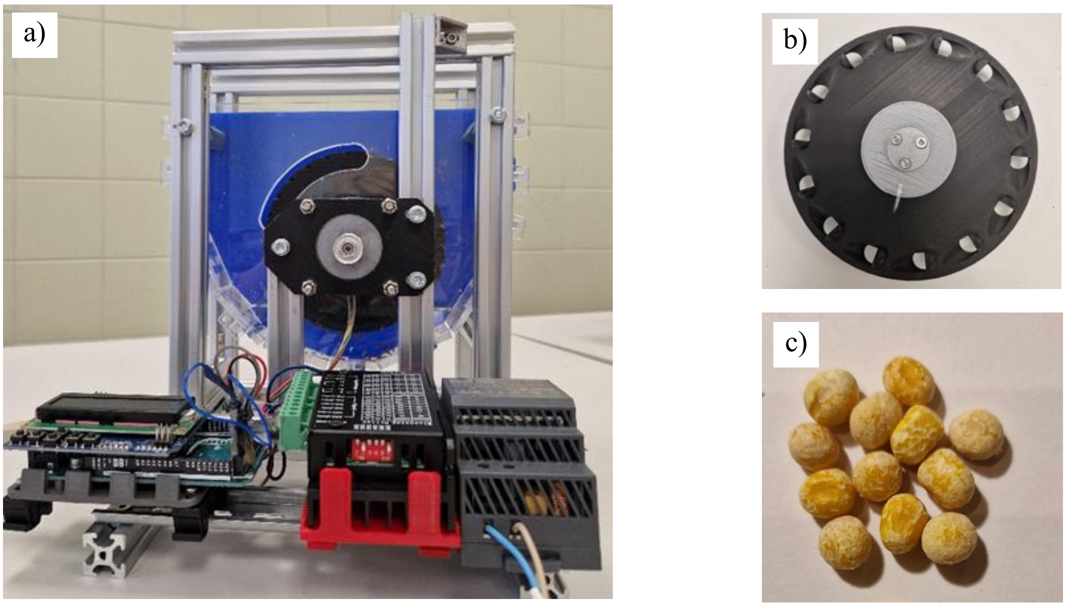


Fig. 1. **Laboratory test:** a – general view of the test bench; b – seed disk; c – pea seeds

Pea seeds (Fig. 1c) were used in the experiment. Seed dimensions were measured using a vernier calliper with a measurement accuracy of 0.01 mm. A total of 10 seeds randomly selected from the sample were measured. To evaluate the uniformity of seed spacing and the seed falling velocity, a high-speed camera Photron FASTCAM-1024PCI with Photron Camera Software was used [5]. The recording and data storage system consisted of (Fig. 2a): a high-speed camera, a camera controller, and a personal computer. The recording settings were 1/1000 s shutter speed and 1000 fps frame rate. The recorded video was subsequently converted into image frames for further analysis. Additional lighting lamps were used to ensure proper illumination during filming.

The seed discharge process was investigated while the disc rotational speed varied from 20 rpm to 50 rpm, with step of 5 rpm. For each test, three-disc revolutions were analysed. Each experiment was repeated three times.

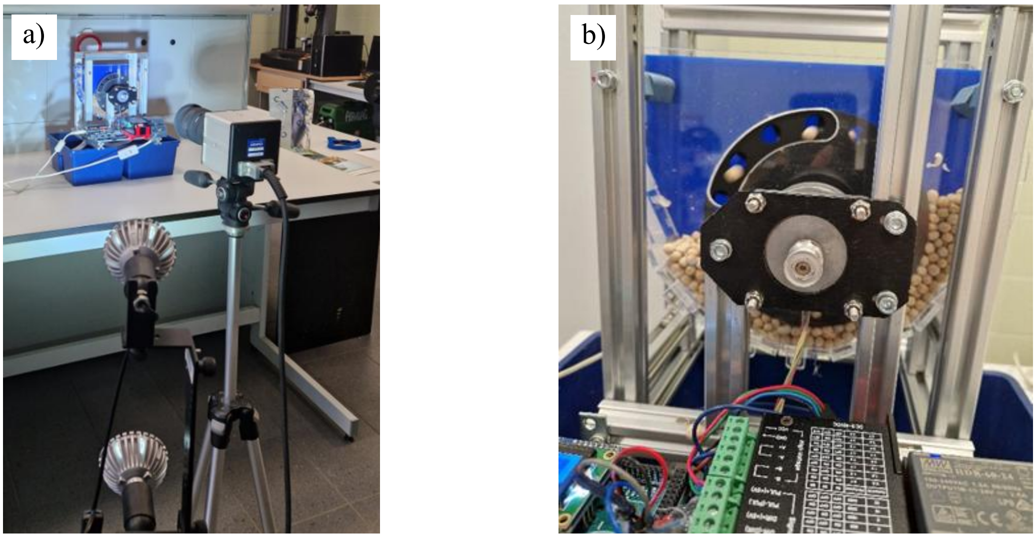


Fig. 2. **Experiment set up:** a – test devices; b – seed metering mechanism with pea seeds

**Results and discussion**

Experimental investigations of seed metering performance were carried out in 2025-2026, in a laboratory based at the Department of Agricultural Engineering and Safety of the Vytautas Magnus University Agriculture Academy (Lithuania).

The dimensions of the pea seeds were measured before the test. Pea seeds are 6.68 ± 063 mm in diameter. The average velocity of the pea centroid was calculated for a 10 mm free fall without contact (Fig. 3a and 3b). Fig. 3a shows the initial reference point used for the calculations, corresponding to the moment when the seed begins to fall. Fig. 3b indicates the final reference point of the calculation. The time interval between seeds was recalculated to a falling height of 82 mm, corresponding to the disk centroid (including the increase in velocity due to gravitational acceleration).

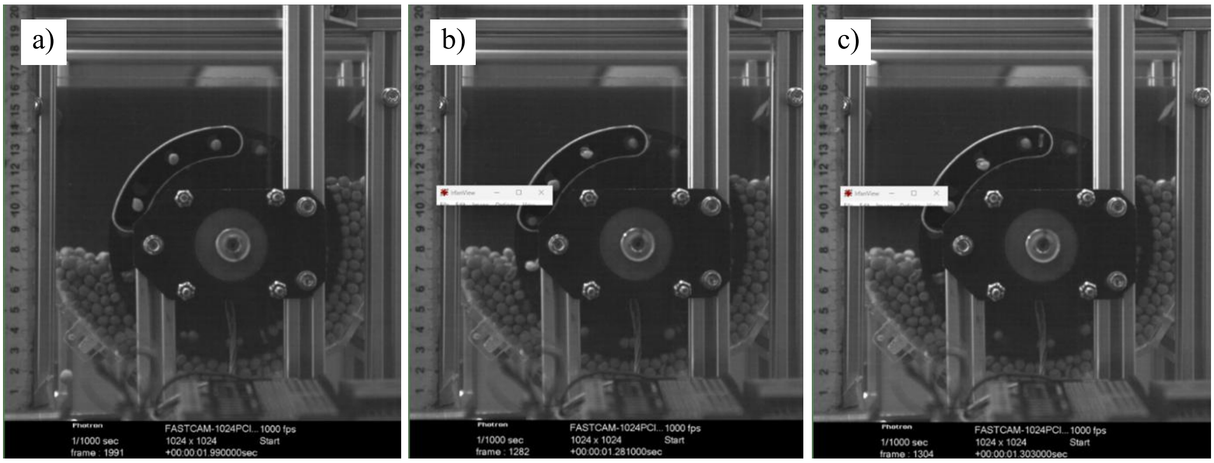


Fig. 3. **Image frames of a high-speed camera:** a) start measurement point of seed falling; b) end measurement point of seed falling; c) seeds in spoons of the disk

The obtained results for the vertical velocity of the seeds and the time interval between successive seeds are presented in Fig. 4.

After analysing the results, it was determined that when the disk rotational speed ranged from 20 to 50 rpm, the vertical velocity of the seeds varied from 0.39 ± 0.02 to 0.69 ± 0.04 m·s$^{-1}$. When the disk rotational speed exceeded 40 rpm, the vertical velocity of the seeds began to increase. The seed falling velocity is a highly important parameter affecting seed distribution uniformity during the seeding process. The increase in seed vertical velocity with higher disk rotational speeds agrees with findings in in the works of other scientists, where seed motion is governed by centrifugal forces and gravity, and higher metering speeds have been shown [6] to raise seed exit velocity and influence spacing uniformity.

Likewise, studies reported in [7] emphasize that maintaining an optimal seed velocity reduces bounce and rolling after soil impact, thereby improving planting accuracy. Therefore, this parameter should be carefully considered in the design and optimization of seeders. In this context, the developed seeder test bench proved to be very successful in accurately measuring and evaluating seed falling velocity, providing a reliable tool for performance assessment and design improvement.

The time interval between successive seeds decreased with increasing the disk rotational speed. The longest time interval between seeds was observed at a disk speed of 20 rpm, whereas the shortest interval occurred at a disk speed of 49.8 rpm. In addition, not only did the mean time interval decrease, but the standard error values also decreased with increasing the disk speed, indicating a more stable and uniform seed flow and consequently improved seed distribution uniformity. The reduction in time interval and variability between successive seeds at higher rotational speeds aligns with conclusions drawn by Kachman and Smith [7], who reported that increased metering frequency generally leads to improved uniformity, if seed damage and miss rates remain controlled. These results demonstrate that the developed test bench was highly successful in evaluating seed flow behaviour and the resulting seed distribution uniformity. Therefore, the system can be effectively used as a practical and reliable alternative to conventional evaluation methods, such as the greased belt technique, for the assessment and optimisation of seed metering systems.

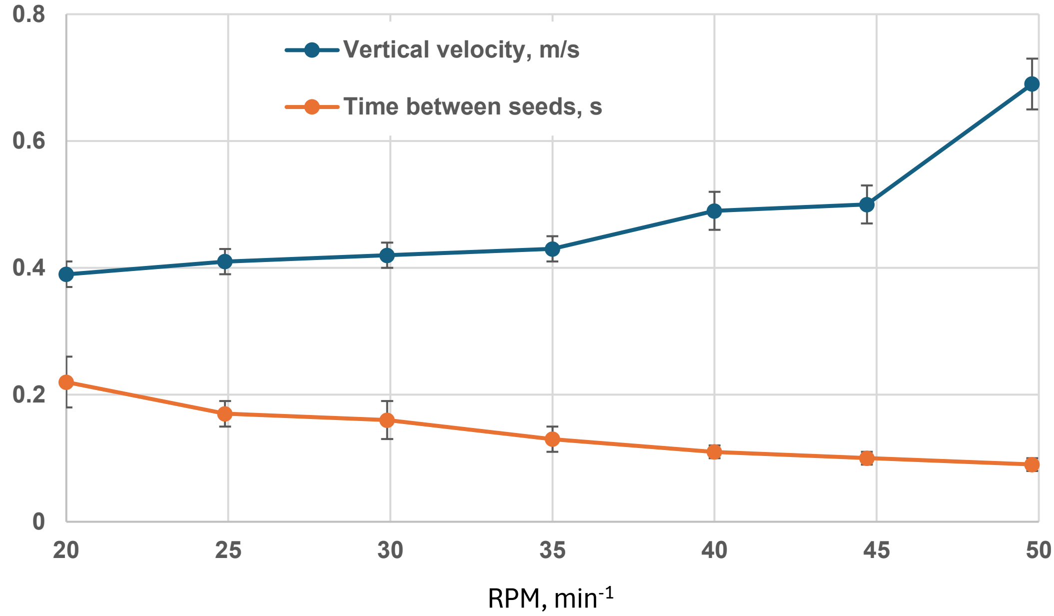


Fig. 4. **Dependence of vertical velocity of seeds and time between seeds on the disk rotation speed**

## Conclusions

1. The results showed that increasing the disk rotational speed from 20 to 50 rpm led to an increase in the seed vertical velocity (from 0.39 ± 0.02 to 0.693 ± 0.04 $m \cdot s^{-1}$) and a simultaneous reduction in the time interval between successive seeds. While this trend was expected, the experimental data provide quantitative relationships that can be used to define an optimal operating range for the seed metering disk. Rotational speeds above 40 rpm resulted in higher seed velocities and reduced variability in time intervals, indicating improved flow stability; however, excessively high velocities may negatively affect seed placement accuracy due to increased impact energy. Therefore, the optimal disk speed should be selected as a compromise between achieving uniform seed release (low variability and consistent spacing) and avoiding excessive seed velocity, with the range of approximately 40-50 rpm identified as a suitable operational window under the tested conditions.
2. The developed seeder test bench proved to be effective for measuring seed falling velocity and analysing seed flow behaviour under controlled laboratory conditions. However, since direct measurements of seed distribution uniformity (e.g., spacing accuracy after soil impact) were not

included in this study, the system should be considered as a complementary tool rather than a complete replacement for established evaluation methods such as the greased belt technique. Nevertheless, the test bench provides valuable insights into key kinematic parameters influencing seed distribution and can support further investigations aimed at optimising seed metering performance and improving precision seeding technologies.

## Author contributions:

Conceptualization, E.J. and DK; methodology, E.J., D.K., H.Y. and S.P.; formal analysis, E.J., D.K., H.Y. and S.P.; investigation, E.J., D.K., H.Y. and S.P.; data curation, E.J., D.K., H.Y. and S.P.; writing – original draft preparation, E.J., D.K., H.Y. and S.P.; writing – review and editing, E.J., D.K., H.Y. and S.P.; visualization, E.J., D.K., H.Y. and S.P.; project administration, E.J.; funding acquisition, E.J. and D.K.;. All authors have read and agreed to the published version of the manuscript.

## Acknowledgments

The research is supported by the Lithuanian Research Council project MIP No. MIP-24-130 "Design, Development, and Evaluation of a Seeder Prototype for Intercropping and Multi-variety Sowing Systems at Variable Sowing Rates".

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