Site Specific Control of Seed-Numbers per Unit Area for Grain Drills

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Abstract

With present day grain drills the number of plants per unit area is controlled via the seed-mass per unit area in kg/ha. This method causes substantial deviations from the target. Instead of the seed-mass the seed-numbers should be controlled. This can be attained by recording the number of seeds passing through the seed tube.

A method is presented which includes a compensating program for recording errors due to seed clusters falling through the tube. It is shown that the actual deviations in the number of seeds recorded with the present day seed rates can be kept below 2,5 %. The method is suitable for automatic closed loop computer control and for side specific sowing.

Keywords: Bulk Seed Metering, Optical Sensor, Exponential Distribution of Seed Distances, Closed Loop Control, On the Go Control, Site Specific Application

Introduction

Agronomists define the seedrate needed by the number of plants per unit area and the field emergence, thus by the number of seeds per unit area. Instead of this with grain drills the farmers try to adjust the seedmass per unit area in kg/ha.

In doing this, they attempt to attain the number of seeds per unit area needed. Yet they have to cope with deficiencies. These can arise from the varying wheel slip due to firm – or soft soil as well as dry - or moist soil. Deficiencies can be due to the varying bulk density of the seeds, since grain drills are designed for bulk- or volume metering. And the bulk density changes with the species, the variety, the provenance, and because of vibrations in the hopper, which influence the settling of the seeds. Finally, rather large deficiencies can arise from the varying average mass per seed. With European wheat varieties the mean mass per seed fluctuates between 40 and 55 mg. We would get rid of all these deficiencies by a reliable method of closed loop control of the seed numbers per unit area. For this, sensing the number of seeds passing through the seed tube seems necessary.

Seed-Distances

With precision drilling the distances between the falling seeds correspond to a normal distribution. Its coefficient of variation with well adjusted machines is only between 10 and 20 %. With bulk drilling the distances between the falling seeds correspond to an exponential distribution (Fig. 1). Its coefficient of variation is 100 % (1, 2, 3, 4, 8).

Precision drilling	Bulk drilling
the distances t between the falling seeds correspond to a normal - or gaussian distribution.	the distances t between the falling seeds correspond to an exponential distribution. The density function is $f(t) = \bar{t}^{-1} e^{-t/\bar{t}}$ The frequency of distances between a and b is: $\int_a^b f(t)\,dt = e^{-a/\bar{t}} - e^{-b/\bar{t}}$
The coefficient of variation is 10 to 20%.	The coefficient of variation is 100%.

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Fig. 1: Conditions for sensing the numbers of seeds

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Fig. 2 shows the frequency of seed distances from experiments with sticky belts. With bulk drilling, contrary to precision drilling, the highest distance frequency does not correspond with the mean seed-distance. The highest frequency is always in the smallest distance range, resulting in distinct seed clusters (Fig. 2).

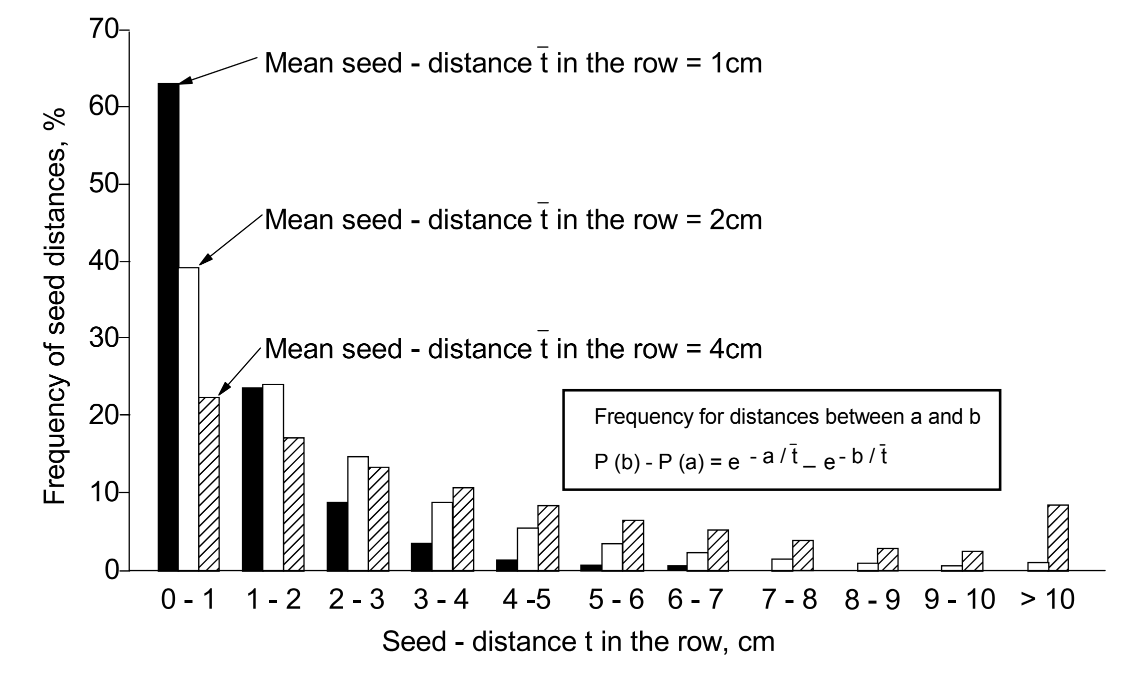

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Fig. 2: Seed distances in the row with bulk - drilling

These seed clusters present a sensing problem (Fig. 3). Multiples, which pass the rays of a light detector at the same time, are recorded as one seed. Considerable deviations in seeds recorded result from this. In addition, a few seeds are missed because the light detector itself has a reaction time. Yet this reaction time of the light detector used was below 1 ms, therefore deviations resulting from this are very small.

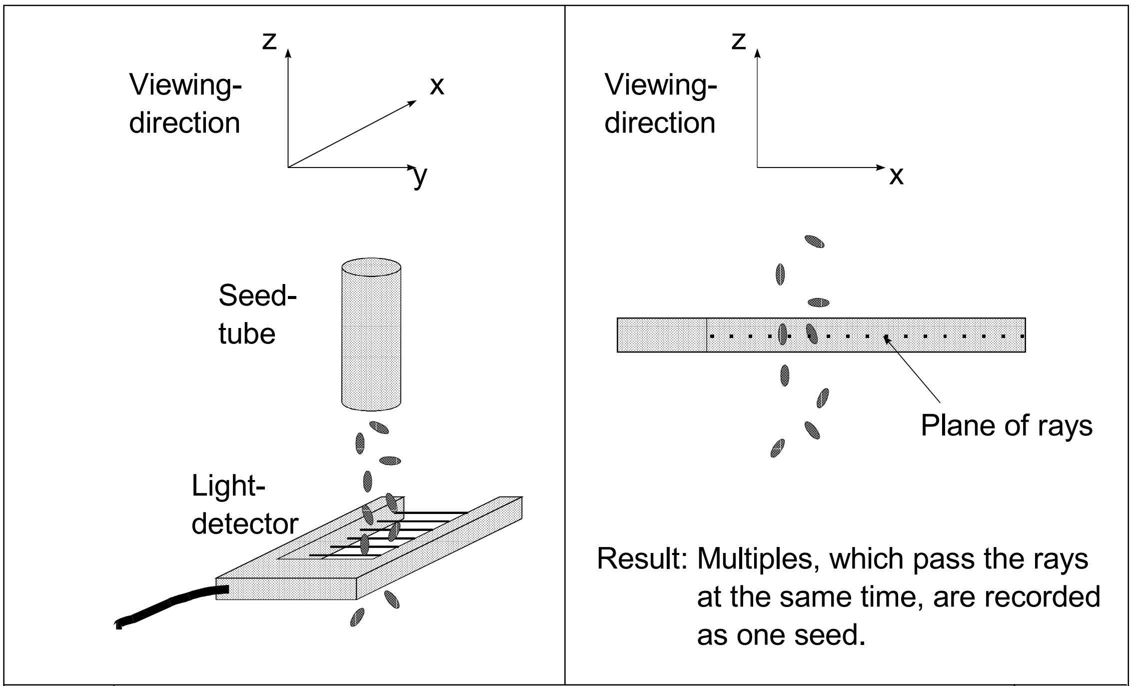

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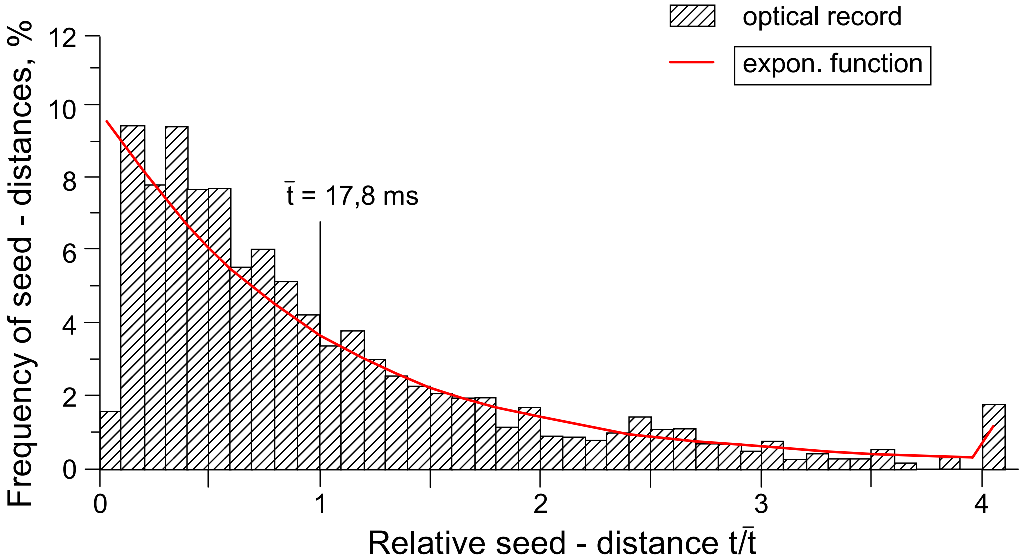
Fig. 3: The situation for optical recording of bulk - metered seeds

However, the multiples occuring with bulk drilling complicate the optical sensing of the seeds. Because of these multiples up to now optical recording of the number of seeds is not used with bulk drilling. With precision drilling these multiples hardly occur, and consequently optical seed counting is common practice.

Optical Recording and its Regression

Fig. 4 shows the results of the optical recording with bulk drilling. The data are presented for relative seed distances by using the ratio between the absolute distances and its mean. This simplifies the situation, since the effect of the average seed distance can now be omitted. Contrary to the frequency of seed distances indicated by the exponential distribution (Fig. 2) there is a distinct decline in the smallest distance range (Fig. 4). This decrease is caused by the sensing problem indicated.

The regression curve based on the exponential distribution in Fig. 4 was obtained by using the least squares method. It does not fit well to the data, which is mainly due to the sensing deficit in the first frequency column.



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If the optical sensor does not record the small seed distances, it still might be possible to compensate for the seeds left out by using the exponential distribution. This is our approach to the problem. The question is, how to obtain the respective exponential distribution. We concluded that if the optical sensor leaves out small seed distances, the least square program should omit this range when computing the regression equation (Fig. 5). But which range of the small seed distances precisely should be left out?

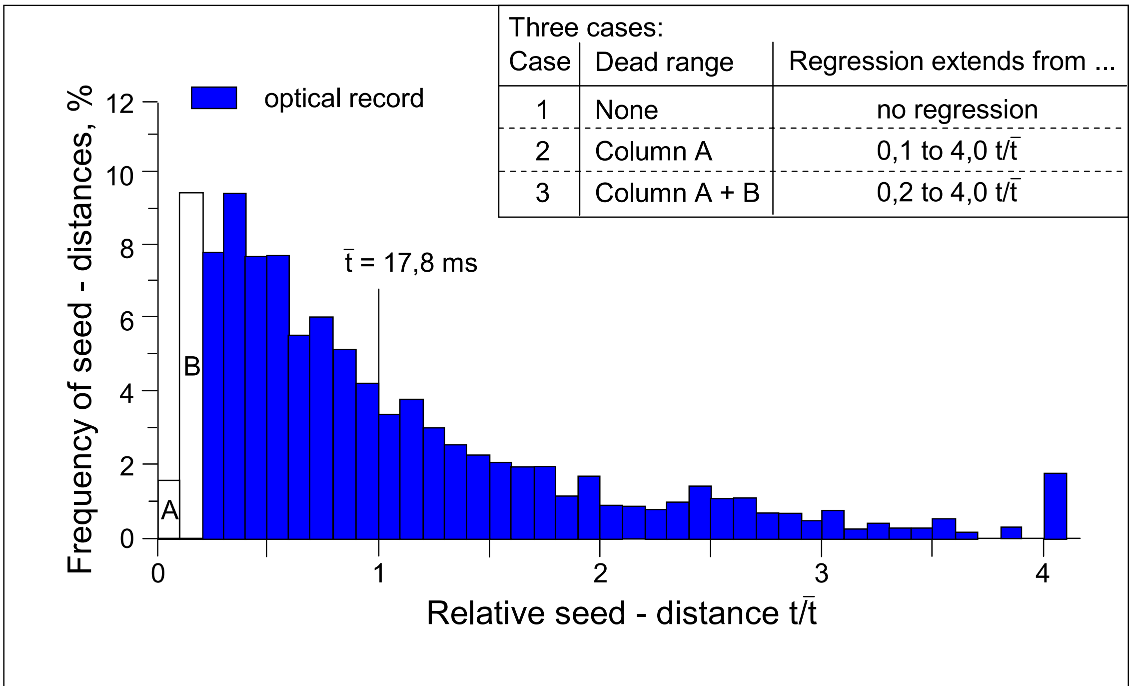

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Fig. 5: Results of the optical recording and dead ranges

The number of seeds actually delivered were compared with the results of three recording methods:

- in case 1 the seeds were only recorded by the optical sensor without any compensation for small distances left out;
- in case 2 the relative seed distances from 0,0 to 0,1 were left out, thus the regression was obtained from the sensor data ranging from 0,1 to 4,0 relative seed distance;
- in case 3 the relative seed distances from 0,0 to 0,2 were left out and thus the regression was based on relative distance data from 0,2 to 4,0.

However, in case 2 as well as in case 3 the regressions obtained were used afterwards to calculate the seeds for the distances left out as well. The regressions served as means for compensating the distances originally left out. So we used the regressions in a way, which every expert of statistics normally will not approve. Yet our aim was not to verify the exponential distribution. We knew from previous work with stickys belts that it holds for the frequencies existing with small grains. Instead, our intention was to make up for the deficiencies in the optical sensing of small seed distances. All results presented refer to wheat, yet in principle hold for other small grain species as well.

Deviations

The deviations from seed numbers actually delivered generally increased with the seed frequency. The optical seed counting without any compensation by regression had a minus deviation of 17 % with a seed frequency of 90 Hertz, which is about the upper limit for small grains. The regression methods with dead recording ranges always were better. However, the regression method with the small dead range gave good results only up to a seed frequency of 60 Hertz. The regression method with extended dead range resulted in deviations below 2,5 % up to a seed frequency of 90 Hertz. So this method seems suitable for small grains (Fig. 6).

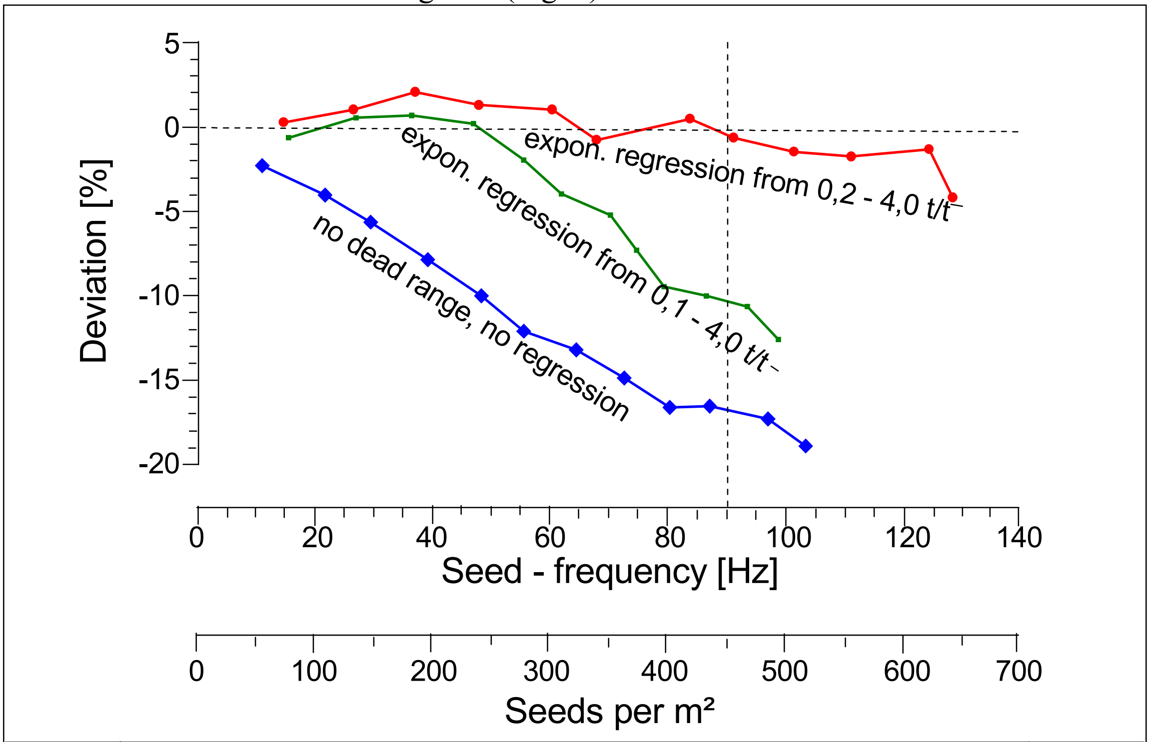

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Fig. 6: Deviations from seeds actually delivered

Closed Loop Control System

Fig. 7 outlines the system used.

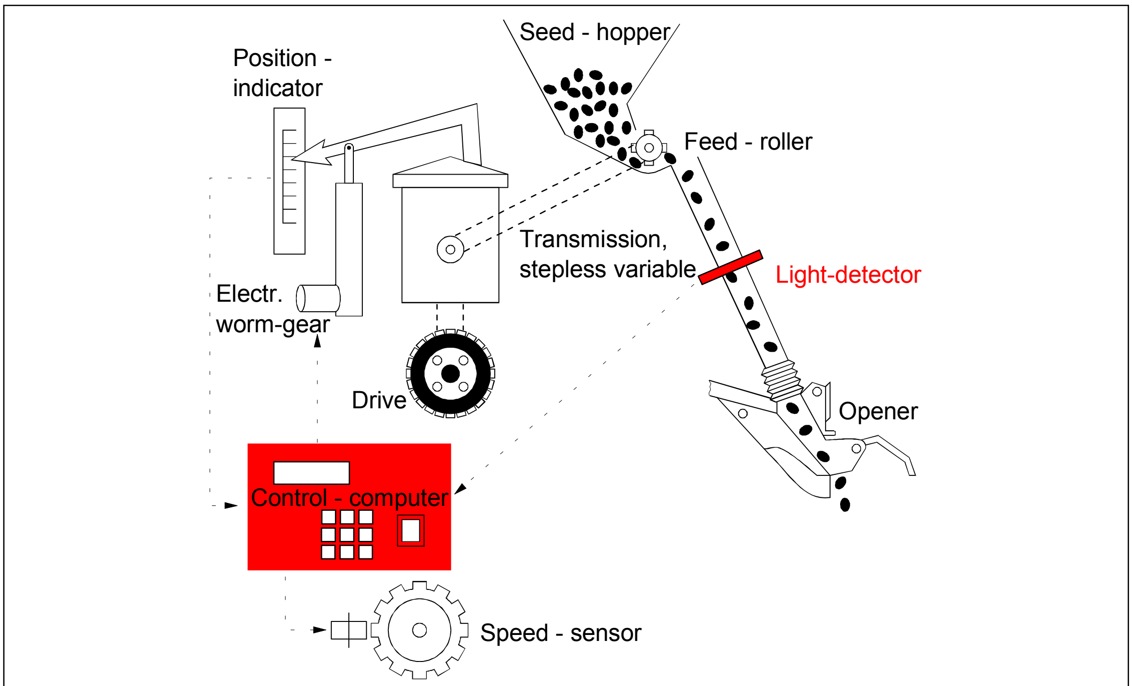

Fig. 7: Closed loop control system for seedrate

The control-computer gets the data from the light detector. If the regression results deviate from the adjusted seed frequency, an electric worm gear is actuated and changes the transmission ratio for the drive of the feed rollers. The control-computer is connected to a speed sensor in order to adapt the seed frequency needed to changing travel speeds. Details are listed in reference 1.

Results and conclusions

The accuracy of closed loop control depends on the amplification within the system. The amplification should suit to the reaction of the transmission ratio on the seed frequency. If the amplification causes overreactions, the control produces excessive fluctuations of the results. Apart from this the question is, how many seeds per control run should be recorded by the optical sensor. The more seeds per control run must be recorded, the slower the control system is.

Fig. 8 shows results from experiments with a suitable control amplification. The experiments are based on a transition from 300 to 400 seeds per m^2. It can be seen that the control curves are still erratic, if less than 100 seeds per control sample are used. The control curve for 200 seeds per sample, however, is as steady as with 500 seeds per sample. So, 200 seeds per sample seem to suffice to get a smooth control curve.

The seed distance within the row with small grains is approximately 2 cm. Thus with 200 seeds per sample a travel distance of 4 m delivers a signal. Therefore, the system is suitable for site specific farming. The influence of wheel slip, bulk density, and average mass per seed on the plant density are eliminated. The farmer can supervise the seeds per unit area on the monitor in the tractor cabin.

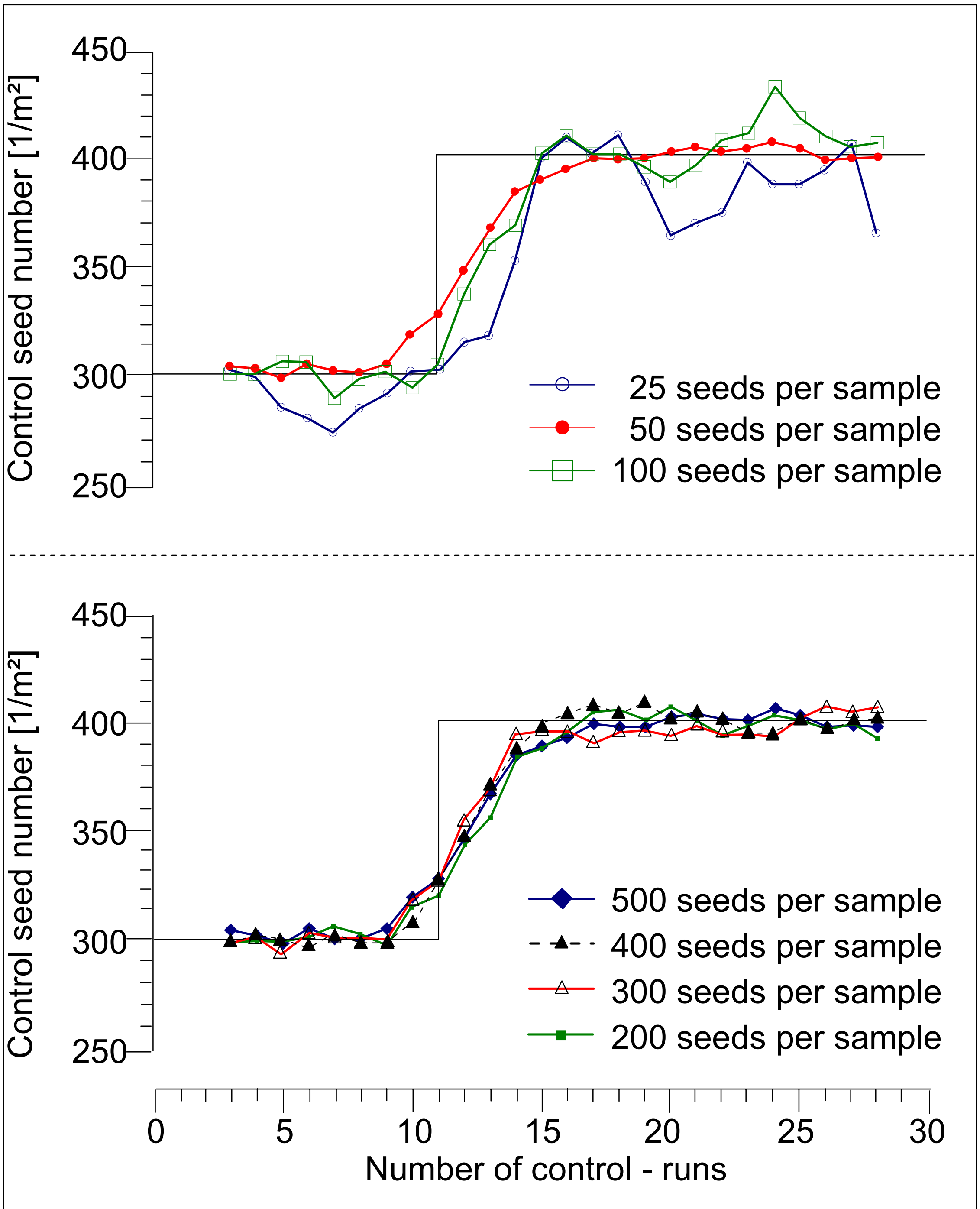

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Fig. 8: Control - curves and seeds per sample

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