AN AUTOMATIC SEQUENTIAL SINGLE-SEED WEIGHING SYSTEM: VARIATION IN SOYBEAN SEED WEIGHT

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Introduction

Uniformity of seed size is an important factor in evaluating seed quality of Japan's bean crops. However, there are few data on seed size variation. One major reason is the time-consuming labor necessary for weighing large numbers of individual seeds.

A slotted sieve method has been used for estimation of seed size variation, but it can not compare seeds which differ in shape. While automatic seed counters are available, an apparatus which can automatically and quickly weigh large numbers of individual seeds has not been available.

The objectives of this paper are to introduce a new automatically-controlled seed weighing system, and to provide some information concerning the seed size variation in soybeans from the first use of this system.

Sequential Single-Seed Weighing System

Constitution and mechanism

The system consists of three major parts: seed picker, digital electronic balance and computer (Fig. 1). The seed picker included a vacuum pump. The balance and computer required an interface for control signals. Several devices were ready-made: Sartorius Model 1204-MP or 1216-MP Balance, Canon Model AX-1 Computer, and Orion Model KRA-3 Vacuum Pump. The seed picker and interface were designed and constructed for this application.

The seed picker automatically removes one seed at a time from a hopper. It delivers the seeds at a regular interval to a bowl on the balance (Fig. 2). The flat surface of the turntable forms a part of one wall of the seed hopper. Two orifices were perpendicularly drilled into the surface of the turntable

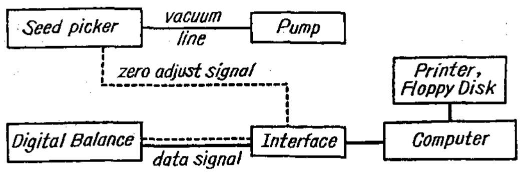

Fig. 1. Block diagram of "Sequential Single-Seed Weighing System".

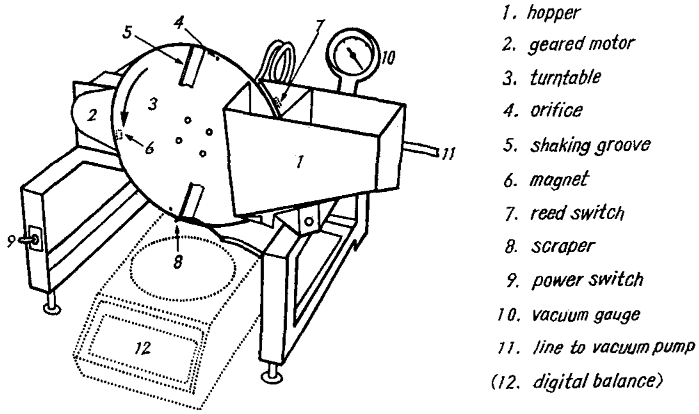

Fig. 2. A view of "Seed Picker".

TABLE 1. Seed picker specifications

vacuum pressure	max. 40 cm-Hg
turntable size	21.5 cm in diameter
orifice size	2 mm in diameter
turntable rotation	12.5 to 15.0 rpm
hopper volume	approx. 1.3 ℓ
overall apparatus size (excluding pump)	50×40×40 (LWH) cm

and connected to the vacuum line. The orifices are located 180° apart and 0.75 cm from the periphery. A scraper, which is attached to the chassis, is positioned above the balance and near the surface of the turntable. Two magnets are mounted on the turntable. They are positioned to activate a reed-switch for the zero-adjustment. Two grooves, 1.5 mm deep, were carved in the turntable surface to shake seeds in the hopper to improve seed pickup (Fig. 2). Specifications of the seed picker are listed in Table 1. The use of vacuum pressure for seed pickup is similar to an existing sowing device (ITO, *et al.*[2]).

The seed picker operates as follows (Fig. 2):

a) A geared motor drives the turntable at a regular speed through the seed hopper.

b) The orifices are kept under negative pressure by the vacuum pump.

c) When an orifice moves through the hopper, only one seed at a time adheres to the turntable, because the seed covers the orifice.

d) When the turntable rotates and a seed is located just above the balance, the scraper displaces the seed from the orifice and the seed drops into the bowl.

e) After the balance stabilizes the data signal of single-seed weight is transmitted from the balance to the computer through the interface.

f) The magnet passes and activates the reed-switch mechanism and the interface commands zero-adjustment (taring) to the balance (Figs. 1 and 2).

g) These operations are repeated until all seeds in the hopper have been weighed.

Performance

The measurement efficiency of this system depends most on the ability of the balance. Specifically, the time for the balance to stabilize and measure a seed weight determines the time required. The total time for measurement includes time for taring, signal transmitting, and program running, but these all are very short. Since the balance which was used here required 1.5 to 2.0 seconds for measuring one seed with 0.01 g readability, the seed picker was adjusted to 2.0 to 2.5 seconds per seed for pickup speed. Approximately 1,500 to 1,800 seeds could be measured per hour.

An orifice size of 2 mm was selected on the basis of minimum size of mature seed in a smallest-seeded variety which wanted to measure. This size seemed adequate for the range of seed size in common varieties of soybean. In order to avoid the injection into the pump of aborted seeds and small pieces of pod wall, seed sample should be screened by a sieve of the same orifice size.

When samples contained many seeds with uneven or wrinkled surface, or vacuum was too high, two or more seeds tended to adhere at one time. For normally matured soybean seeds, however, such multiple pickup could be avoided by cotrol of vacuum pressure. On the other hand, when seeds in the hopper formed bridges, or vacuum was too low, the apparatus failed to pick up seeds. The formation of bridges under the adequate pressure was almost completely eliminated by the grooves in the turntable which shook seeds in the hopper (Fig. 2). Our preliminary observation showed that soybean seed size ranged from less than 0.05 g to more than 0.70 g among varieties. Since correct pickup depended on the relationship between seed size and vacuum level, optimum pressure were chosen according to variety to maintain continuous correct measurements.

Although this system was developed for soybean seeds, it seemed applicable to other seed crops. For example, some kidneybean (*Phaseolus vulgaris* and adzuki bean (*Vigna angularis*) varieties could also be measured. Because of considerable differences from soybean in seed shape or size, some specifications of the seed picker (Table 1) might need to be changed to avoid frequent mis- or multi-seed pickup.

The computer program for this system converts each datum of seed weight into a class frequency and then adds it to a frequency distribution which is recorded on a floppy disk for each seed lot. Of course, data processing can be changed by computer programing as occasions demand.

Materials and Methods

Two soybean varieties, Tokachinagaha and Harosoy, were planted on 20 May 1978 at a population of 33,000 plants per 10 a with a row spacing of 30 cm. Seeds were harvested and screened with a 2 mm-sieve. Seeds infested with disease and insect (less than 0.2% in number) were eliminated by hand. Two hundred samples (100 seeds/sample) were taken at random from lots of each variety and then individual seed weights of each sample were measured using the sequential seed weighing system. Data were recorded as class frequency with 0.01 g interval in each sample. After the measurement of all samples, frequencies of 100-seed weights and 100-seed C. V. s (coefficients of variation of single-seed weight in 100 seeds) were calculated. Mean and standard deviation of these characteristics were also calculated. After weighing seeds individually, smaples were separated by shaking on a stack of five sieve which ranged from 5.5 mm to 7.5 mm with 0.5 mm interval in solt diameter. For each 2,000 seeds which remained on each sieve (about 300 seeds in a 7.5 mm-sieve) single-seed weight was measured and their mean and standard deviation were calculated by means of the system. The seed moisture content of both varieties was about 11%.

Results and Discussion

Seed yields were about 350 kg per 10 a in both varieties, similar to those in average year, but their visual intraplant variations were considerably large, probably because of high population density.

Fig. 3 shows the frequency distributions for 100-seed weight and 100-

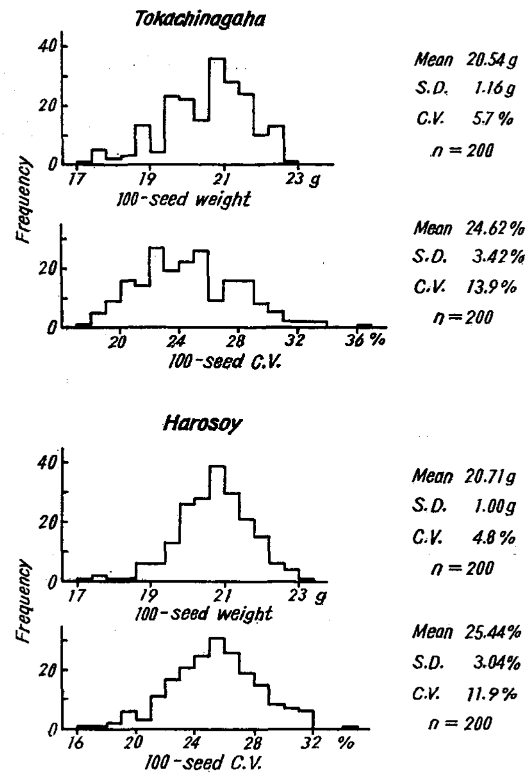

Fig. 3. Frequency distribution of 100-seed weight and 100-seed C. V. (coefficient of variation of single-seed weight in 100 seeds) in soybeans.

seed C. V. Distribution profiles of both characteristics were nearly normal as expected from the "central limit theorem". 100-seed weight distributed to relatively wide range of 17 g to 23 g, wehereas coefficients of variation of that were 6% and 5% in Tokachinagaha and Harosoy, respectively. Assuming normal distribution, about 70% of 100-seed weight would be included within 20 ± 1 g in both varieties. Thus, 100-seed weight was a proper index of average seed size. On the other hand, it was difficult to estimate the seed size variation for the whole lot from 100-seed C. V. Because C. V. s of 100-seed C. V. were two times those of 100-seed weight, 14% for Tokachinagaha and 12% for Harosoy.

The frequency distribution of single-seed weight in the whole sample was shown in Fig. 4. The curved line in the figure represents the expected frequency on the assumption of normal distribution which was calculated as follows :

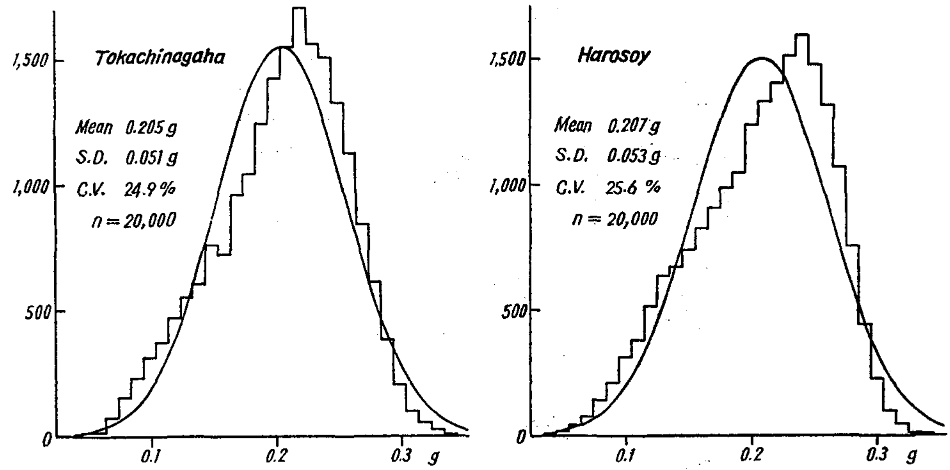

Fig. 4. Frequency distribution of single-seed weight in soybeans under the high population density (33,000 pl./10 a). Curved line shows normal distribution estimated by sample mean and standard deviation.

$$Y=\frac{20,000}{100s\sqrt{2\pi}}\exp\left(-\frac{(X-\bar{x})^2}{2s^2}\right)$$

where, Y is number of seeds at class X (seed weight with 0.01 g interval), $\bar{x}$ and s are sample mean and sample standard deviation, respectively. Apparently, the normal distribution did not fit for single-seed weight in both lots of Tokachinagaha and Harosoy. The mode of distribution was located in a larger seed class than mean size; the histogram had negative skewness. According to tests of normality the probability of fitnesses was less than 0.5%. MIYAGAWA[2], in his study of provability distribution, regarded the distribution of single-seed weight in normally grown soybean seed as normal distribution. Although each seed size was determined physiologically by the amounts of assimilate, it could be assumed that there might be a genetically reasonable size and many seeds would converge near-by that size in the process of normal maturation. Then the frequency of larger seed classes might be less than that of smaller classes for the mode. Our results seemed to support this assumption.

As stated in the beginning of this paper, a set of hole slotted sieves has been used at times to estimate seed size variation for the reason of its easy handling. In this case seed size should be expressed as not "weight but "size", being separated by each hole diameter of sieves. Although weight and size are essentially differed concepts, they have been generally used with the same meaning in quantitative expression of crop yield characteristics,

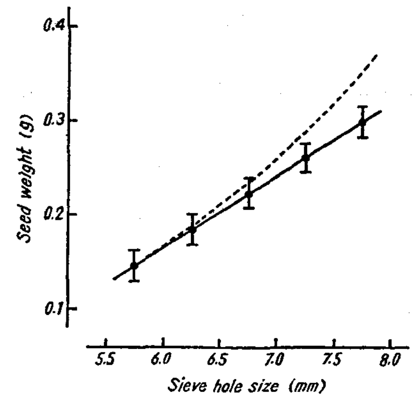

Fig. 5. Relationship between sieve hole size and seed weight in soybean (var. Tokachinagaha). Dashed line shows the expected seed weight on the assumption all seeds had a similar shape and the same specific gravity as in seeds that remained a 5.5 mm-sieve. Vertical bars show standard deviation of seed weight on each sieve. About 8,300 seeds were measured.

especially of bean seeds. In order to compare the estimation of seed size variation precisely, we should clarify the relationship between weight and size of seed. Fig. 5 shows the relationship between sieve hole size and seed weight in Tokachinagaha. If all seeds of sample had similar shape and same specific gravity, single-seed weight would be proportional to cube of one dimension (in soybean that would be seed width) in seed size. However, the observed relationship between sieve hole size and seed weight was completely linear in two varieties ($r=1.000$ for Tokachinagaha and $r=0.999$ for Harosoy). This result indicates that individual seeds differed little by little in shape and specific gravity. In any case, within one soybean variety the difference between estimating seed size using weight basis or size basis is insignificant.

Summary

A new automatically-controlled system could sequentially weigh approximately 1,500 to 1,800 individual soybean seeds per hour with 0.01 g readabilty. The principle of this system may be applicable for other crop seeds.

For each of two soybean varieties, Tokachinagaha and Harosoy, 20,000 seeds was measured using this system. Repeatability of 100-seed weight was very good, but of 100-seed C. V. (coefficient of variation of single-seed weight in 100 seeds) was not so good. Frequency distribution of single-seed

weight in 20,000 seeds differed from normal distribution in both varieties. The relationship between size of seeds which were separated by sieves and individual seed weights was linear within each variety.

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