



## Application Note 010: Reproducibility of Length Measurements

Introduction:

The manual inspection and measurement of rice grains is a slow and tedious operation. Humans are prone to variations due to tiredness, lighting, judgement and many other external influences. Image analysers, such as SeedCount, offer an objective means of making measurements of physical parameters, including length and width, with better precision and accuracy.

The objective of this study was to establish the reproducibility of length measurements with the SeedCount software using white rice as the sample seeds.

Procedure

Experiment 1: Determine the reproducibility of the SeedCount vs manual inspection.

10 seeds were selected from a sample of rice and were measured with a digital calliper. Three (3) different people (A, B and C) measured the same 10 seeds, three time each. The same 10 seeds were measured using the SeedCount Image Analyser. 20 analyses were performed on the 10 seeds. For each analysis, the seeds were placed in different positions on the tray (top, bottom, wide and narrow) in order to maximise the errors as much as possible.

Experiment 2: Determine the accuracy of the length measurement made by the SeedCount.

The 10 seeds were scanned 20 times in order to obtain the average of the length of all the seeds contained in the whole tray. After each analysis, the tray was emptied and refilled with the exact same sample in order to rotate the position of the kernels and maximise the differences between measurements.

Results

Experiment 1: The results obtained by the person A are expressed in table 1.

Seed #	Person A				
	A1	A2	A3	Avg	StdDev
1	7.53	7.41	7.58	7.51	0.09
2	6.47	6.16	6.48	6.37	0.18
3	6.76	6.28	6.26	6.43	0.28
4	7.52	7.46	7.46	7.48	0.03
5	6.90	6.81	6.77	6.83	0.07
6	7.49	7.42	6.94	7.28	0.30
7	7.12	7.21	7.15	7.16	0.05
8	7.59	7.36	7.38	7.44	0.13
9	7.75	7.47	7.60	7.61	0.14
10	6.36	6.25	6.32	6.31	0.06

Table 1 – Digital calliper results obtained by Person A

After, person B measured the same 10 seeds and the results obtained are expressed in table 2.

Seed #	Person B				
	B1	B2	B3	Avg	StdDev
1	7.59	7.29	7.60	7.49	0.18
2	6.52	6.50	6.53	6.52	0.02
3	6.61	6.68	6.21	6.50	0.25
4	7.41	7.32	7.53	7.42	0.11
5	7.03	6.85	6.78	6.89	0.13
6	7.24	7.21	7.28	7.24	0.04
7	6.95	7.12	7.04	7.04	0.09
8	7.12	7.28	7.19	7.20	0.08
9	7.46	7.50	7.64	7.53	0.09
10	6.18	6.11	6.12	6.14	0.04

Table 2 – Digital calliper results obtained by Person B

Finally, table 3 presents the results obtained by person C.

Seed #	Person C				
	C1	C2	C3	Avg	StdDev
1	7.23	7.29	7.32	7.28	0.05
2	6.28	6.37	6.32	6.32	0.05
3	6.47	6.57	6.40	6.48	0.09
4	7.40	7.42	7.45	7.42	0.03
5	6.95	6.98	7.23	7.05	0.15
6	7.23	7.06	7.24	7.18	0.10
7	6.88	7.00	7.04	6.97	0.08
8	7.14	7.25	7.21	7.20	0.06
9	7.62	7.42	7.48	7.51	0.10
10	5.98	6.06	6.08	6.04	0.05

Table 3 – Digital calliper results obtained by Person C

In order to compare the results, tables 4 and 5 present the results obtained by SeedCount after 20 scanned images:

Seed #	Samples (mm)										
	1	2	3	4	5	6	7	8	9	10	11
1	7.2	7.2	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.3
2	6.3	6.3	6.2	6.2	6.3	6.3	6.4	6.4	6.2	6.2	6.3
3	6.5	6.5	6.6	6.6	6.6	6.5	6.5	6.6	6.6	6.6	6.6
4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.5	7.5	7.5
5	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.9	7.0	7.0	7.1
6	7.3	7.3	7.2	7.3	7.2	7.2	7.3	7.3	7.2	7.1	7.1
7	6.9	6.9	7.1	7.0	7.0	6.9	6.9	7.0	6.9	7.0	7.1
8	7.0	7.0	7.2	7.3	7.3	7.1	7.1	7.1	7.0	7.1	7.1
9	7.5	7.5	7.6	7.5	7.5	7.4	7.4	7.4	7.4	7.4	7.4
10	6.0	6.0	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.1

Table 4 – Results first 10 images

Seed #	Samples (mm)										Avg	StdDev
	12	13	14	15	16	17	18	19	20			
1	7.2	7.2	7.2	7.3	7.4	7.2	7.3	7.2	7.3	7.24	0.07	
2	6.4	6.4	6.4	6.3	6.3	6.3	6.4	6.3	6.4	6.32	0.07	
3	6.9	6.9	6.9	6.6	6.6	6.7	6.5	6.5	6.5	6.62	0.13	
4	7.4	7.4	7.5	7.5	7.6	7.6	7.5	7.4	7.5	7.46	0.07	
5	7.2	7.2	7.2	7.2	7.2	7.1	6.9	6.9	7.0	7.05	0.11	
6	7.1	7.1	7.1	7.2	7.2	7.1	7.3	7.2	7.3	7.21	0.08	
7	7.1	7.1	7.2	7.0	7.1	7.1	7.1	7.0	7.0	7.02	0.09	
8	7.1	7.1	7.1	7.3	7.4	7.1	7.1	7.2	7.1	7.14	0.11	
9	7.4	7.4	7.6	7.5	7.5	7.5	7.5	7.4	7.4	7.46	0.07	
10	6.1	6.1	6.2	6.1	6.3	6.1	6.1	6.1	6.2	6.10	0.07	

Table 5 – Results last 10 images

Experiment 2: Table 6 shows the average length of each scanned image, as well as the total average and the standard deviation of the values.

Sample	Avg Length
1	7.08
2	7.09
3	7.09
4	7.09
5	7.12
6	7.08
7	7.07
8	7.08
9	7.13
10	7.13
11	7.13
12	7.14
13	7.15
14	7.14
15	7.11
16	7.14
17	7.11
18	7.15
19	7.14
20	7.19
<b>Avg</b>	<b>7.12</b>
<b>StdDev</b>	<b>0.03</b>

Table 6 – SeedCount overall length average measurements

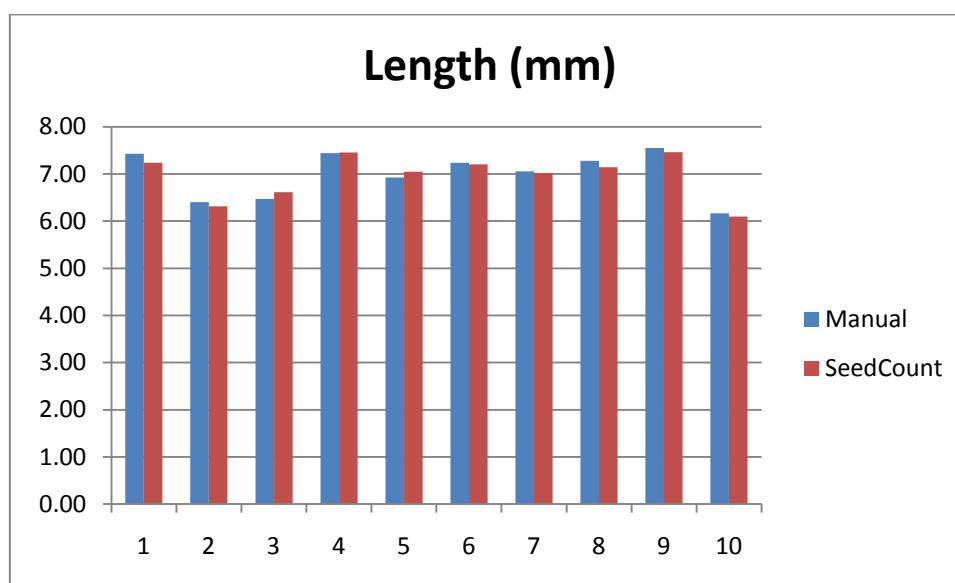
Discussion:

Table 7 shows these results of the three manual measurement, ie, digital calliper. The average length of each seed and the standard deviation for each measurement are shown in table 7..

Seed	Person A			Person B			Person C			Avg	StdDev
	A1	A2	A3	B1	B2	B3	C1	C2	C3		
1	7.53	7.41	7.58	7.59	7.29	7.60	7.23	7.29	7.32	7.43	0.15
2	6.47	6.16	6.48	6.52	6.50	6.53	6.28	6.37	6.32	6.40	0.13
3	6.76	6.28	6.26	6.61	6.68	6.21	6.47	6.57	6.40	6.47	0.20
4	7.52	7.46	7.46	7.41	7.32	7.53	7.40	7.42	7.45	7.44	0.06
5	6.90	6.81	6.77	7.03	6.85	6.78	6.95	6.98	7.23	6.92	0.15
6	7.49	7.42	6.94	7.24	7.21	7.28	7.23	7.06	7.24	7.23	0.17
7	7.12	7.21	7.15	6.95	7.12	7.04	6.88	7.00	7.04	7.06	0.10
8	7.59	7.36	7.38	7.12	7.28	7.19	7.14	7.25	7.21	7.28	0.15
9	7.75	7.47	7.60	7.46	7.50	7.64	7.62	7.42	7.48	7.55	0.11
10	6.36	6.25	6.32	6.18	6.11	6.12	5.98	6.06	6.08	6.16	0.13

Table 7 – Overall results of manual measurements

These averages must be contrasted with the lengths calculated by SeedCount. A graphic comparison can be seen in the histogram 1.



Histogram 1- Length comparison between the 10 selected seeds

It can be seen from the tables 5 (SeedCount) and 7 (Manual) that the average of the standard deviations of the measurements obtained using the SeedCount Image Analyser, ie, 0.09mm, are less than the measurements by the 3 people using a digital calliper ie, 0.13mm.

Subsequently, it is possible to calculate the average of all the selected seeds. Using tables 4 and 5, the length average obtained with SeedCount is 6.96 and the one produced by manual measurements is 6.99, based on the numbers expressed on table 7. Taking in consideration that the instrument's precision is 0.1mm, it is concluded that the measurements are in range.

Moving to the Experiment 2, table 6 presents a standard deviation of 0.03 between 20 different scanned images.

It is important to clarify that in the sample there were some broken seeds which the software ignores in the calculation of the average length of the studied scanned image. Also, anytime a tray is filled with a new sample, some of these broken seeds share the same indent with a whole kernel and therefore the software will recognise it as a single plus broken case and will not be taken in consideration for the average. Similarly, when more than one seed shares an indent (doubles or triples), they are not part of the whole count. Finally, it is imperative to consider the hardware's precision of 0.1 mm and therefore, as we have proven, not all the seeds will measure exactly the same all the time.

All the arguments exposed above are the reason why the same sample can give different, but similar, results. A standard deviation of 0.03 is a good indicator of reproducibility.

## Conclusion

It can be concluded that the SeedCount equipment can reproduce accurate length measurements. Also, it has been proven that one seed does not have a unique true length value but a measured value and an uncertainty that depends on the errors surrounding the system. From Experiment 1, it is concluded that manual measurements produce a higher uncertainty than the ones generated by SeedCount.

Probabilistically, one or ten seeds do not truly represent a sample of 1000 kernels. The Experiment 2 demonstrates the reproducibility of the equipment for a full tray.