An Automated System For Vigor Testing Three-Day-Old Soybean Seedlings

A.L. Hoffmaster[1*], K. Fujimura[1], M.B. McDonald[2], M.A. Bennett[2]

[1]Department of Computer and Information Science
[2]Department of Horticulture and Crop Science
The Ohio State University, Columbus, OH 43210-1086

Abstract

An image processing computer application to automatically assess the vigor of three-day-old soybean (*Glycine max* [L.] Merrill.) seedlings was developed. The software operates on acquired digital images of soybean seed lots placed on a paper towel. Soybean seedlings were extracted away from the paper towel and converted into various digital representations. These representations were used to analyze the seedlings and segment them into normal and abnormal categories. The normal seedlings were further processed so that a one-pixel-wide summary structure of the shape of the seedling was produced. From this summary structure, the software classified the seedlings into six type categories based on their shape. Each normal seedling was processed to remove the cotyledon portion of the summary structure based on the type category it fell into. The remaining summary structure, with the cotyledon removed, was then used to compute the length of each seedling in pixels. From these length measurements, speed of growth and uniformity of growth values were computed. These two values were normalized and combined into a zero to 1,000 vigor index for the seed lot. Combined with the post-processing corrective features, this computer software was able to achieve highly accurate and standardized measurements of each soybean seedling, providing an alternative to the current method of manually measuring soybean seedlings for speed and uniformity of growth when performing a vigor test.

Introduction

Seed vigor is defined as "those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions" (AOSA, 1983). A seed vigor test is a series of analyses on a seed lot that provide an indication of its emergence potential in the field. While there are many different ways to measure a seed lot's vigor, one of the most important is to determine a seed lot's speed and uniformity of growth as described in the seed vigor definition.

The two main limitations of performing a vigor test manually are 1) results of a vigor test may vary from laboratory to laboratory because of the subjective nature of most vigor tests and 2) many vigor tests take excessive time to acquire results. These two limitations were addressed by designing computer software that measures the seedlings represented by a digital image and computes the vigor index from those measurements.

Materials & Methods

After being germinated for 3 days, an image of the soybean seedlings was acquired with a large scanning box that allowed the placement of two flatbed scanners side by side. The scanners were operated in serial by a controlling software application to obtain two images that were combined together to represent all 50 seedlings (Figure 1).

From this image, the soybean seedlings were segmented away from the dark brown paper towel background and converted into various digital representations. These representations included a list of pixel positions representing each seedling's silhouette (binary object) and a 1-pixel wide summary structure referred to as a skeleton (Hilditch, 1969).

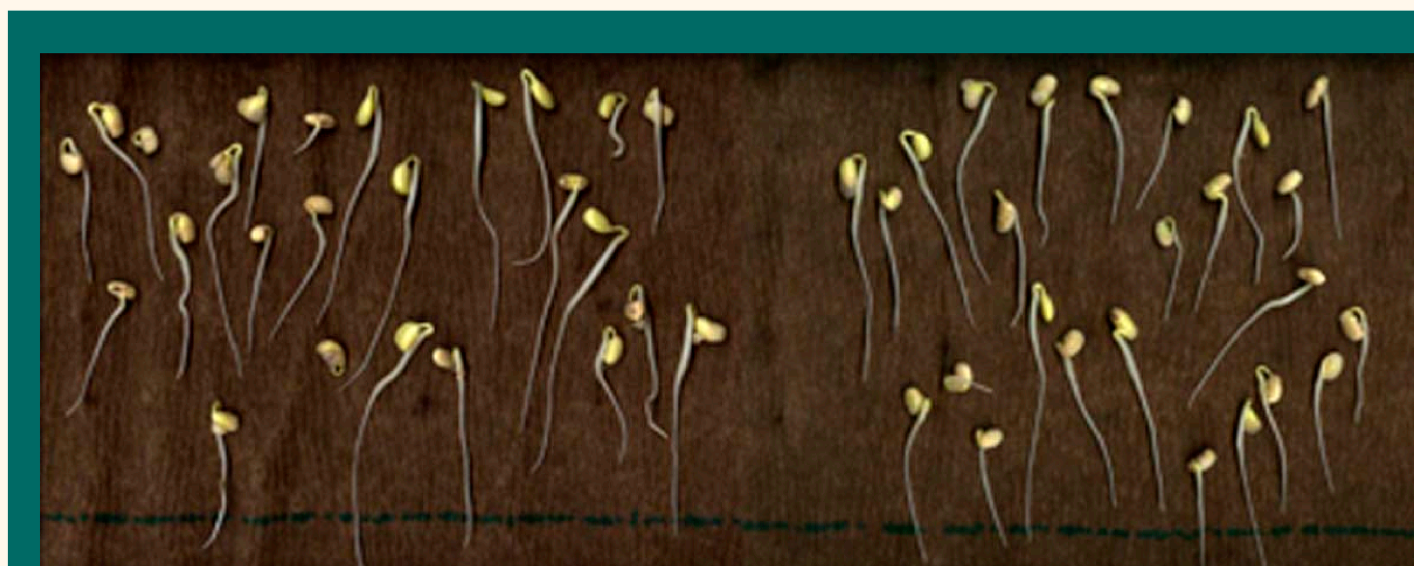

Figure 1. Sample seedling input image.

From these digital representations, the seedlings were classified as normal or abnormal. Normal seedlings were further processed for length measurements. The main challenge in measuring the normal seedlings was that the cotyledons of the seedlings do not contribute to growth and, therefore, should not be measured. As a result, unique methods were developed to remove the cotyledon portion of the seedling skeletons so that the overall lengths of the hypocotyl and radicle of the seedling were measured.

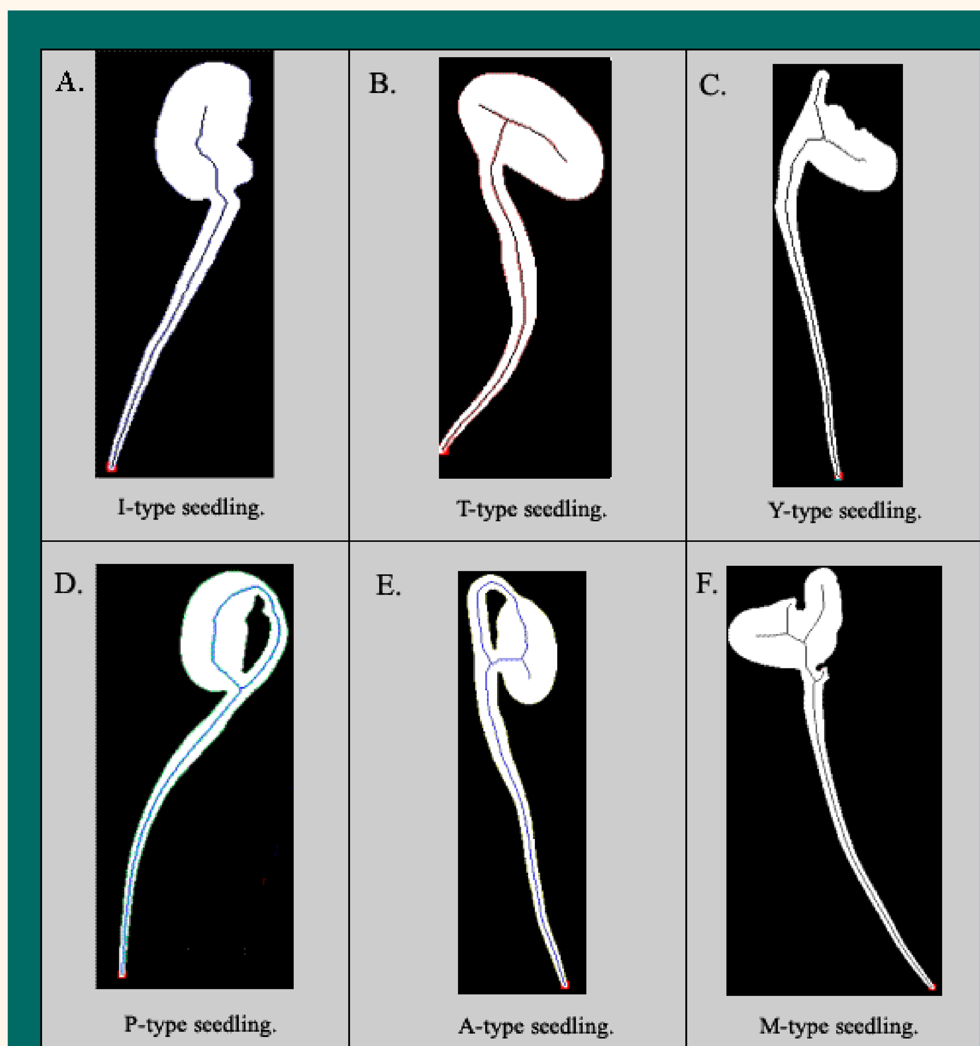

Figure 2. Soybean seedling type examples.

To remove the cotyledons, the seedlings were classified into alphabetic type categories based on structural similarities. The six types represented by the software were the I, T, Y, P, A, and M-type seedlings **(Figure 2)**. The I-type seedling had no branches. The T-type seedling had branches occurring entirely within the cotyledon. The Y-type seedling had branches extending further away from the seedling compared to the T-type with one branch representing measurable length. The P-type seedlings had a loop, and the A-type seedlings had a loop and an extra branch. M-type seedlings were a "catch-all" type and represented miscellaneous seedling structures. 20% of the total seedlings examined to date were M-type seedlings. M-types often had extra branches or loops in their skeletons.

In processing the seedlings, the goal was to remove the portion of the seedling's skeleton that summarized the cotyledon. The remaining skeleton would only reflect the hypocotyl and radicle that could be subsequently quantified to derive length measurements necessary to compute the vigor index. The cotyledons were removed from the skeletons by measuring the width of the seedling along the skeleton and detecting fluctuations in the width that indicated when the cotyledon was encountered. The method for removing the cotyledon was slightly different for each seedling type (Hoffmaster, 2002), taking advantage of observations specific to seedlings falling into each type.

After removing the cotyledons, the skeletons of the seedlings were quantified to produce length measurements for each seedling. These length measurements were combined into speed and uniformity of growth values whose weighted sum was used to produce a 0 to 1000 vigor index representing the vigor of the seedlings. The speed of growth value was dependent on the ratio of actual measured length to the maximum possible length for the seedlings found in the image. The uniformity of growth value was inversely proportional to the standard deviation of the length measurements for the seedlings.

Results

The software achieved success in most situations by removing the cotyledons so that the remaining hypocotyl and radicle were measured **(Figure 3)**.

Through the development of this soybean imaging system, a fast, objective, and reproducible method to perform a seed vigor test on soybean seedlings was achieved. For every input example presented to the software, a seed vigor index was derived in less than 20 seconds. This was a significant improvement over manually measuring the seedlings, which may take up to 30 minutes. Another advantage of the soybean system was its objective and reproducible results. If the software processed an input image representing the seedlings multiple times without invoking the corrective features of the software (Hoffmaster, 2002), the vigor index produced was exactly the same.

Even though this system was designed specifically for soybean seedlings, it also shows promise for other seedlings with similar structure. The principles of the soybean system were also applied successfully to three-day-old cotton seedlings and impatiens seedlings to produce vigor indices and/or length measurements (Hoffmaster, 2002). Through extensions of the principles of this soybean system, seed vigor assessment systems for other crops are possible.

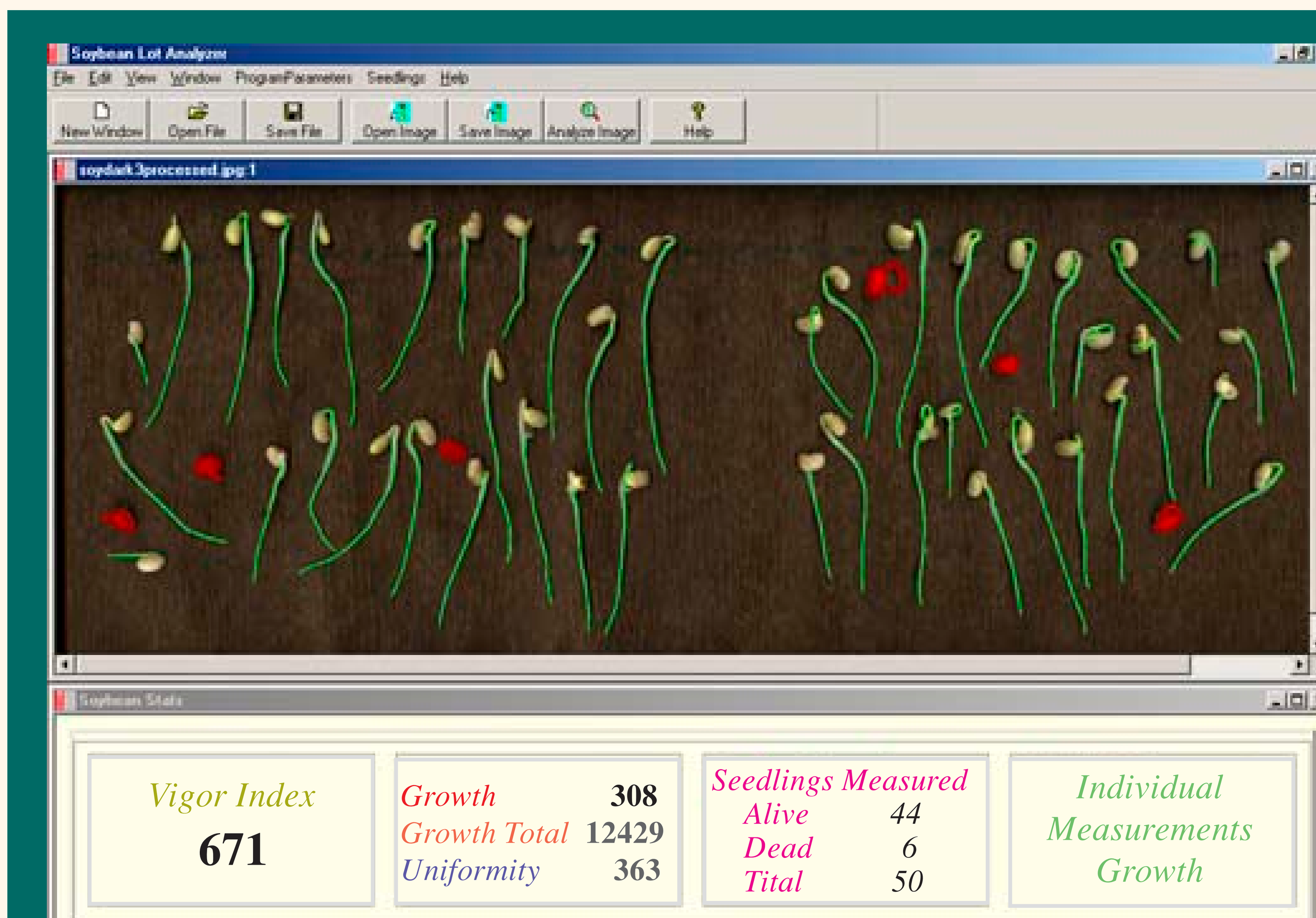

Figure 3. Seedling processing results-measured length reflected by green lines overlaid on normal seedlings. Abnormal seedlings are in red. Note that the green lines do not extend into the cotyledons.

References

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