Application of Computer Vision Technology on Seed Conditioning and Parameter Determination of Zhengdan958 Corn Variety (Zea Mays L.)

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Abstract. In order to provide clear data support for corn seeds conditioning and parameter selection, and get the optimal selection results for specific seeds batches, we used seed identification software to extract the color and morphology traits of 304 single kernels of Zhendan958 corn variety, and analyzed the correlation of these physical parameters with seedling fresh and dry weights. The results showed that the width, length, projection area, Blue, b, and S of the endosperm are significantly correlated with the fresh weight of each seedling, with a correlation coefficient exceeding 0.5 and a coefficient of variation of over 10%, which means if we sort seeds according to these traits, we could get good seed processing results. When using the selection criteria Blue > 160, b < 30, Saturation ≤ 30, width < 8 mm, length < 9 mm, and projection area < 50 mm², the average fresh weight of the resulting seedlings increased by 1.0233, 1.0250, 1.0250, 1.0325, 1.0295, and 1.0250 g, respectively, which represents an increase of at least 6%. Verification test in the same seed batch validated our results. This kind of test could be used in seed processing factory and determine the optimal seed conditioning procedures and parameters.

Introduction

Maize is the most important grain crop and livestock-feed source and plays a key role in China’s food security. Seeds are the most important element for agricultural production. For various crops, selecting high-quality seeds is crucial for increasing the yield. For each given variety of maize, the seed-selection technique is very important because it ensures seed quality and thus maize yield [1]. Now, seed processing plants mainly are depending on technicians’ experience to determine the seed conditioning process and parameters, fraction of seed companies use lab electrical screens to pre-screening, but only two indicators (seed width and thickness) could be tested and determined. But there inevitably exist differences in the physical traits among different varieties of the same crop, even among the different seed batches harvested in different production years and places. Analyzing the correlation between seed physical properties and seed vigor is helpful in selecting the optimal seed conditioning process and parameters for specific seed batch, in order to achieve the highest seed quality improvement effect.

Now, with the advent of advanced image-processing techniques, automated seed sorting has attracted increasing interest. Computerized image processing (also called digital image processing) converts images into digital form to be analyzed by computer, and the fast development of computer technology facilitates the extensive and convenient application of this technology in agriculture[2]. Wiwart et al. (2012) used image processing and principal component analysis to identify wheat varieties according to shape features (Feret's diameter, roundness, aspect ratio, solidity) and color descriptors of hue, saturation, and intensity (HSI) and L*a*b*[3]. Peng et al. (2013) extracted the physical characteristics of 400 cotton seeds by using automated seed-identification software. The correlation with germination rate was analyzed to obtain HSB parameters and the width, length, and projection area of desirable seeds[4].
techniques are being increasingly applied to determine maize quality and for precise processing of rice[5,6].

In the present work, we use the seeds of the maize hybrid Zhengdan 958. Information regarding the embryo and endosperm of each seed was extracted by using seed identification software developed at the China Agricultural University with VS2010, C#, OPENCV and an ACCESS database (software copyright number 2013SRBJ0528). The seed identification software automatically obtains seed information such as RGB, Lab, HSB, gray, length, width, and projection area and can export data and images. The identification error is < 2% and all types of seed can be identified provided they do not touch each other. The system response time, the processing time, and the export time are all < 10s. The number of identified seeds depends on the scanners and the seed variety. For maize seeds, we identified a maximum of 600 seeds at one time. After seven days of germination, standard germination experiments were done to obtain the fresh and dry weights of seedlings. The results were analyzed to search for correlations, based on which the selection indicators and parameters were screened.

Materials and Methods

Experimental Apparatus

Images were generated by using Scanner (Uniscan D6810, China), then were recognized by seed identification software and data were processed by the IBM SPSS Statistics 17.0 and Excel 2010. Seed thickness was measured with a SF2000 three-key digital caliper.

Experimental Method

The ears of maize hybrid Zhengdan 958 were collected in 2015 in the ZhangYe province, China. Four columns of seeds from three maize ears were selected at random and arranged sequentially. The maize seeds were placed sequentially on the glass plate of the scanner to generate images of the embryo and endosperm. The images were saved in PNG format and used for automated seed identification. The sampling size, font size, and offset were 20×20, 13, and 20×130, respectively. RGB, Lab, HSB, gray scale, width, length, and projection area of each seed were recorded. Seed thickness was measured with a digital caliper.

For the germination experiment, the seeds were numbered and disinfected by rinsing for 5 min in 1% NaClO3 solution. After three rinses with deionized water, paper rolling (38#Anchor, USA) was used in a standard germination experiment at 25 °C. The fresh weight of each seedling was measured on 7th day. To measure the dry weight, the seedlings were first deactivated at 105 °C in a DHG-9023A air-blow dryer for 0.5 h and then dried at 80 °C for 24 h.

For statistical processing, all data were analyzed by using the IBM SPSS Statistics 17.0 software package.

Finally, an experiment was done to verify the above results: other seeds samples of corn hybrid Zhengdan 958 were sorted by the indicators and parameters described above, followed by seed vigor test.

Results

Correlation between Seedling Fresh and Dry Weight and Seed Physical Traits

Tables 1 and 2 showed the physical traits of the embryo and endosperm of Zhengdan 958 maize seeds and their correlation with seedling fresh and dry weight, respectively; As shown in Table 1, significant correlation appeared between embryo thickness, Red, a, b and Hue, Saturation, Brightness and the fresh and dry weights of the seedlings, respectively. However, the correlation coefficients did not exceed 0.5. Conversely, the correlation coefficients between width, length, and projection area and fresh and dry weights of the seedlings were all greater than 0.5, indicating an extremely significant correlation. The coefficients of variation for thickness, a, b, Saturation, width, length, and projection area all exceeded 10%. For some traits, the coefficients of variation exceeded
30%. Therefore, width, length, and projection area can be used as selection indicators.

In Table 2, all the traits exhibit an extremely significant correlation with the fresh and dry weights of seedlings. The correlation coefficients between Green, Blue, Lightness, a, b, Saturation, gray scale, width, length, projection area, and the fresh and dry weights of seedlings all exceed 0.5. The coefficients of variation of Blue, a, b, Saturation, width, length, and projection area all exceed 10%, with the highest being 45%. The trait of a was not suitable as a selection indicator because of the high repetition of data. Thus, the final selection indicators are Blue, b, Saturation, width, length, and projection area.

| Table 1. Physical traits of embryo and correlation with seedling fresh and dry weight. |
|---------------------------------------------------------------|
| **Embryo** | **Minimum** | **Maximum** | **Average** | **Standard deviation** | **Coefficient of variation (%)** | **Correlation with seedling fresh weight** | **Correlation with seedling dry weight** |
|---|---|---|---|---|---|---|---|
| Red | 206 | 254 | 233.66 | 6.45 | 2.76 | 0.413** | 0.322** |
| Green | 188 | 249 | 218.14 | 7.68 | 3.52 | 0.185* | 0.111 |
| Blue | 121 | 234 | 188.84 | 12.81 | 6.78 | 0.001 | -0.046 |
| Lightness | 77 | 98 | 87.78 | 2.66 | 3.03 | 0.227** | 0.141 |
| a | 0 | 7 | 2.12 | 0.78 | 36.75 | 0.388** | 0.393** |
| b | 8 | 40 | 16.67 | 3.93 | 23.59 | 0.224** | 0.233** |
| Hue | 37 | 45 | 39.22 | 1.33 | 3.39 | -0.402** | -0.372** |
| Saturation | 8 | 46 | 19.18 | 4.37 | 22.77 | 0.214** | 0.230** |
| Brightness | 81 | 100 | 91.64 | 2.59 | 2.83 | 0.401** | 0.310** |
| Gray scale | 189 | 248 | 218.99 | 7.61 | 3.48 | 0.213** | 0.137 |
| Width (mm) | 5.14 | 11.08 | 9.06 | 1.08 | 11.97 | 0.777** | 0.848** |
| Length (mm) | 5.66 | 12.95 | 11.23 | 1.44 | 12.84 | 0.777** | 0.714** |
| Thickness (mm) | 3.60 | 9.96 | 5.60 | 0.96 | 17.18 | 0.253** | 0.528** |
| Projection area (mm²) | 21.86 | 97.91 | 78.59 | 16.24 | 20.66 | 0.874** | 0.860** |

Note: (1) “a” represents the range from red to green, “b” represents the range from blue to yellow. (2) The asterisk (*) indicates a significant correlation at the 0.05 level. The double asterisk (**) indicates extremely significant correlation at the 0.01 level (same as Table 2).

| Table 2. Physical traits of endosperm and correlation with seedling fresh and dry weight. |
|---------------------------------------------------------------|
| **Endosperm** | **Minimum** | **Maximum** | **Average** | **Standard deviation** | **Coefficient of variation (%)** | **Correlation with seedling fresh weight** | **Correlation with seedling dry weight** |
|---|---|---|---|---|---|---|---|
| Red | 213 | 244 | 230.84 | 5.46 | 2.37 | -0.242** | -0.425** |
| Green | 169 | 227 | 199.25 | 10.63 | 5.33 | -0.689** | -0.718** |
| Blue | 100 | 189 | 133.01 | 17.09 | 12.85 | -0.522** | -0.645** |
| Lightness | 72 | 91 | 82.00 | 3.34 | 4.07 | 0.585** | 0.661** |
| a | 1 | 11 | 5.22 | 2.37 | 45.40 | 0.679** | 0.632** |
| b | 19 | 46 | 37.80 | 5.51 | 14.59 | -0.362** | -0.498** |
| Hue | 36 | 45 | 40.73 | 1.97 | 4.85 | -0.679** | -0.665** |
| Saturation | 21 | 55 | 42.47 | 6.62 | 15.59 | 0.711** | 0.704** |
| Brightness | 84 | 96 | 90.53 | 2.18 | 2.41 | 0.249** | 0.425** |
| Gray scale | 174 | 227 | 200.63 | 9.35 | 4.66 | 0.549** | 0.842** |
| Width (mm) | 4.87 | 11.24 | 9.06 | 1.11 | 12.28 | 0.416** | 0.731** |
| Length (mm) | 6.36 | 12.95 | 11.22 | 1.50 | 13.33 | 0.876** | 0.853** |

Determination of Seed Vigor

The data analysis reveals that the average fresh weight of seedlings is 0.9622 ± 0.2749 g (standard deviation), and the fresh weight of seedlings minus the standard deviation is equal to 0.6873 g. The seeds were classified into three categories according to the standard-deviation method: low-vigor seeds whose fresh weight of seedlings was ≤ 0.6873 g, medium- vigor seeds whose fresh weight of seedlings was >0.6873 g and ≤ 0.9622 g, and high- vigor seeds whose fresh weight of seedlings was >0.9622 g. The percent of seeds with low, medium, and high vigor is 11.8%, 30.9%, and 57.3%, respectively.
respectively. These results showed that the frequency of seedling fresh weight being below 0.5g is very low. The high frequency of seedling fresh weight occurs at ~1.0g.

**Seed Selection for Zhengdan 958 Maize Hybrid Based on Selection Indicators**

Table 3 gives the distribution of the fresh weight of seedlings for different intervals of Blue, b, S, width, length, and projection area of the endosperm (Peng et al., 2013). The indicator Blue correlates negatively with the fresh weight of seedlings. After sorting based on the criterion Blue > 160, the average fresh weight of seedlings increased by 1.0233 g (6.35%). According to the criteria b < 30, Saturation ≤ 30, width < 8 mm, length < 9 mm, and projection area < 50 mm², the average fresh weight of seedlings increased by 1.0250 g (6.35%), 1.0250 g (6.53%), 1.0325 g (7.31%), 1.0295 g (7.00%), and 1.0250 g (6.53%), respectively. These results showed that, after selection according to the above criteria, the fresh weight of seedlings increased by 6%.

Table 3. Results of seed sorting according to above-mentioned indicators.

| Number of seeds | Total number of seeds | Low vigor seeds | Medium vigor seeds | High vigor seeds | Average fresh weight (g) | Increase of fresh weight (%) |
|-----------------|----------------------|----------------|-------------------|-----------------|--------------------------|------------------------------|
| Blue ≤ 133      | 304                  | 36             | 94                | 174             | 0.9622                   |                              |
| ≥ 133-160       | 190                  | 4              | 54                | 132             | 1.0523                   |                              |
| > 160           | 26                   | 24             | 2                 | 0               | 0.3628                   |                              |
|                | Sort as ≤ 160        |                |                   |                 |                          | 1.0233                      | 6.35                        |
| b < 30          | 24                   | 24             | 0                 | 0               | 0.2884                   |                              |
| 30-40           | 162                  | 12             | 64                | 86              | 0.9684                   |                              |
| > 40            | 118                  | 0              | 30                | 88              | 1.0906                   |                              |
|                | Sort as ≥ 30         |                |                   |                 |                          | 1.0250                      | 6.53                        |
| Saturation ≤ 30 | 24                   | 24             | 0                 | 0               | 0.2884                   |                              |
| 30-50           | 260                  | 12             | 94                | 154             | 1.0170                   |                              |
| > 50            | 20                   | 0              | 0                 | 20              | 1.1291                   |                              |
|                | Sort as ≥ 30         |                |                   |                 |                          | 1.0250                      | 6.53                        |
| Width ≤ 8      | 32                   | 26             | 4                 | 2               | 0.4084                   |                              |
| 8-10            | 228                  | 10             | 84                | 134             | 1.0142                   |                              |
| > 10            | 44                   | 0              | 6                 | 38              | 1.1273                   |                              |
|                | Sort as ≥ 8          |                |                   |                 |                          | 1.0325                      | 7.31                        |
| Length ≤ 9     | 28                   | 26             | 2                 | 0               | 0.3489                   |                              |
| 9-12            | 158                  | 10             | 64                | 84              | 0.9767                   |                              |
| ≥ 12            | 118                  | 0              | 28                | 90              | 1.1003                   |                              |
|                | Sort as ≥ 9          |                |                   |                 |                          | 1.0295                      | 7.00                        |
| Projection area ≤ 50 | 24 | 24             | 0                 | 0               | 0.2884                   |                              |
| > 50            | 100                  | 12             | 54                | 34              | 0.8943                   |                              |
| ≥ 80            | 180                  | 0              | 40                | 140             | 1.0976                   |                              |
|                | Sort as ≥ 50         |                |                   |                 |                          | 1.0250                      | 6.53                        |

Results of Verification Test

We sorted other seeds samples of Zhengdan 958 maize hybrid from the same batch to according to the criteria width < 8 mm, length < 9 mm, and projection area < 50 mm², the fresh weight of seedlings increased by 3.19%, 4.33%, and 3.13%, respectively.

Conclusion and Discussion

The indicators width, length, projection area, and seed thickness; Red, a, b, Hue, Saturation, Brightness for the embryo; and Red, Green, Blue, Lightness, a, b, Hue, Saturation, Brightness, and gray scale for the endosperm correlated significantly with the fresh and dry weights of seedlings of the maize hybrid Zhengdan 958. The correlation coefficients of width, length, and projection area for seed and Blue, b, and Saturation for endosperm with seed vigor all exceeded 0.5, and the corresponding coefficients of variation exceeded 10%. Thus, the appropriate indicators for selecting
seeds of the maize hybrid Zhengdan 958 are Blue, b, Saturation, width, length, and projection area.

Over the past 20 years, nondestructive techniques for seed inspection have drawn increased attention. Some commonly used techniques are machine vision, x-ray analysis, chlorophyll-fluorescence labeling, and spectrometry[7]. Lurstwut and Pornpanomchai(2016) presented a machine vision application for rice-seed germination analysis through image processing and on the basis of color, size, and texture features. Fast-inspection techniques are available for seed processing, measuring the physical properties of seeds, seed priming, and seed aging[8].

Traditional corn seeds conditioning methods include techniques based on color, specific gravity, and size (length, width and thickness). The rapid development of seed industry requires higher seed processing effect based on specific variety even specific seed batch. In this paper, with computer vision technology, we analyzed the correlation between seed physical properties and seed vigor, then supplied reference for selecting the optimal seed conditioning process and parameters. In our experiment, the projection area was highly correlated with seed vigor, and the correlation coefficient was high. In recent several years, with the rapid development of color sorter, Sorting seeds according to seed projection area have come to true.

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References
[1] S. A. Goggi, L. Pollak , J. Golden, M. Devries, G. Mcandrews, K. Montgomery. Impact of early seed quality selection on maize inbreds and hybrids. Maydica, 52(2007) 223–233.
[2] J. C. Ascough, D. L. Hoag, G. S. McMaster, W. M. Frasier. Computer use and satisfaction by Great Plains producers: ordered logit model analysis. Agron. J., 94 (2002) 1263–1269.
[3] M. Wiwart, E. Suchowilska, W. Lajszner, L. Graban. Identification of hybrids of spelt and wheat and their parental forms using shape and color descriptors. Comput. Electron. Agr., 83(2012) 68-76.
[4] J. Peng, Z. Xie, L. Yang, B. Sun, J. Wang, Q. Sun. Quickly selection for cotton seed based on seed identification software (in Chinese). T. Chinese Soc. Agr. Eng., 29 (2013) 147-152
[5] K. Wen, Z. Xie, L. Yang, B. Sun, J. Wang, Q. Sun. Computer vision technology determines optimal physical parameters for sorting JinDan 73 maize seeds. Seed Sci. and Technol., 43(2015) 62-70
[6] Merya, J. Jorge, Chanona-Pérezb, A. Sotoa, J. M. Aquileraa, A. Ciprianoa, N. Veléz-Riverab, I. Arzate-Vázquezb, G.F. Gutiérrez-Lópezb. Quality classification of corn tortillas using computer vision. J. Food Eng., 101 (2010) 357–364.
[7] Dell’Aquila. Development of novel techniques in conditioning, testing and sorting seed physiological quality. Seed Sci. and Technol., 37(2009) 608–624.
[8] Lurstwut, C. Pornpanomchai. Application of image processing and computer vision on rice seed germination analysis. Int. J. Appl. Eng. Res., 11(2016) 6800-6807.