

Evaluation of color and texture characteristics of cereal grains by SeedCounter application

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Motivation and aim: Evaluation of grain coat characteristics is an important task, since they are associated with a number of important biological functions: moisture absorption, grain viability, resistance to pre-harvest germination. The coloration of the grain shell in cereals is due to the content of various metabolites and pigments such as carotenoids, anthocyanins, and melanins. The presence of pigments in the shell affects various technological properties of the grain. For example, phlobaphenes, which give red coloration to the pericarp of the grain, have a positive effect on the duration of grain dormancy and prevent preharvest germination. Also, color characteristics, as well as the appearance of the grain shell, are important indicators of plant diseases. In addition to color, grain texture is also of interest. For example, grain coat roughness in wheat is a trait that is associated with susceptibility of grains to pest damage, technological properties of grain, and moisture content. When studying the mechanisms of genetic control of certain grain traits, breeders and geneticists face the need to evaluate the color and textural characteristics of their shells. Thanks to improvements in digital technology, the quality of color reproduction and detail on modern camera models, including smartphones, is getting better and better, which allows us to estimate the characteristics of plant organs with high accuracy. The previously developed SeedCounter application has shown its practical usefulness in morphometry of wheat and barley grains. The updated version includes an expanded set of computable features, support for new imaging protocols and an updated interface for the mobile version.

Methods and algorithms: The new version of the application implemented the calculation of color characteristics of grains, which include: average intensity values of color channels and dominant color descriptor. The computation of texture features based on the Gray Level Co-occurrence Matrix (GLCM) and the Gray Level Run-length Matrix (GLRM) was also implemented. It is important that color and texture features are computed taking into account grain image masks, because when computing features on a rectangular area, background pixels can introduce significant distortions in the computed features due to the small size of grains and their ellipsoidal shape. In addition, support for various image capture protocols, such as using a standard-size sheet of paper and ColorChecker Mini Classic (<https://calibrite.com/us/product/colorchecker-classic-mini>), is implemented.

Results: The updated version of the SeedCounter application was used to analyze red-grained winter soft wheat accessions. The evaluations made it possible to compare genetic variations of the studied accessions, color characteristics of grains and their resistance to preharvest germination. Based on our method, it was shown that variations in color shades (blueness and lightness) exist in red-grain varieties. As a result, 26 loci associated with grain color traits (including new ones) were identified along with twelve loci associated with preharvest germination resistance traits. In addition, wheat grain images of the International Triticeae Mapping Initiative (ITMI) population including 116 genotypes (1740 images) were analyzed. Analysis of the textural characteristics of the collection showed significant differences between individual genotypes (Synthetik_R93, Opata, ITMI_11, ITMI_103, ITMI_115, ITMI_42, ITMI_62, ITMI_82, ITMI_88) in terms of such characteristics as: mean, homogeneity, uniformity, and correlation.

Conclusions: The updated SeedCounter application expands the possibilities for determining color and textural characteristics of cereal grains. Color traits can be useful to investigate the content of pigments and metabolites in the grain coat, such as carotenoids, anthocyanins, melanins. Textural attributes may be useful for evaluating grain surface characteristics such as roughness. Realized color features allow the detection of subtle differences in grain hues even between samples having the same color type. This approach allows the identification of loci associated with color traits. The SeedCounter application allowed the identification of new loci controlling grain color traits independent of the preharvest germination resistance trait. The analysis of textural traits demonstrated that in the ITMI soft wheat population there is grain diversity in terms of grain coat roughness, which can be detected and analyzed based on the proposed algorithms for grain texture evaluation.

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