NOTE

Discrimination Between Arthur and Arkan Wheats by Image Analysis[1]

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ABSTRACT

A canonical function for discriminant analysis was developed to differentiate between wheat cultivars Arthur (soft red winter) and Arkan (hard red winter) examined by image analysis. In four samples of either Arthur or Arkan selected by the Federal Grain Inspection Service/U.S. Department of Agriculture to vary widely in morphological characteristics, 235 out of 240 kernels were identified correctly. Similarly, 208 of 209 kernels of Arkan from six wheat heads (three from each of two locations) were identified correctly. The discrimination between Arthur and Arkan was successful when samples were examined in the presence of eight other hard red winter or soft red winter wheat cultivars.

Differentiation among wheats of various classes and varieties by the Federal Grain Inspection Service (FGIS) of the U.S. Department of Agriculture (USDA) is based primarily on grain morphology (Anon. 1957, 1984). The cross between the hard red winter (HRW) cultivar Sage (C.I. #17277) and the soft red winter (SRW) cultivar Arthur (C.I. #14425) yielded the cultivar Arkan (C.I. #475771). Arkan has milling and breadmaking properties of an HRW wheat cultivar (Martin et al 1983). Its morphological characteristics, however, are those of the SRW parent Arthur. This report describes the use of image analysis to distinguish between Arkan and Arthur.

MATERIALS AND METHODS

Three heads each of Arkan wheat harvested in 1984 from Manhattan or Hutchinson, KS, were used. The number of kernels from each head ranged between 29 and 43 (average 35). In addition, four samples of Arthur and Arkan wheat, each containing 30 kernels, were obtained from the FGIS/USDA. These samples were selected to represent as wide a variation as possible in morphological characteristics of the two cultivars from various locations. Broken, shrunken, immature, and very small kernels (below about 20 mg) were separated and not used.

The image analyzer Quantimet 720 used a DMA interface to a DEC PDP-11 computer, and software generated displays back to the Quantimet. The whole unit was linked to a CMS-IBM VM/370, which made it possible to handle the data transferred by the interfaced computer and to use off-line data processing. The operating system gave access to all facilities in an "immediate" mode, when results of the proposed measurement were seen at once, or in a "program" mode, when the instruction was entered into a measurement routine.

The image analyzer digitized a camera (vidicon) image and next established the threshold level; feature values were then calculated and stored for subsequent treatment. Even with good image contrast, several precautions needed to be taken to assure proper detection; to assure reproducibility of results, the calibration was measured daily and the shade correction reset.

We developed strategies to optimize methodology, both with regard to correctness of sample preparation and measuring techniques.

The quality of the image was controlled by adjusting the illumination from four halogen lamps; to enhance resolution, the image was magnified optically with an f = 75 magnifier and a 10-mm extension ring. In each measurement, we introduced a plastic calibration sphere close in color to the natural color of wheat and a wheat calibration kernel.

We developed a computer routine to calculate morphology parameters. Computer routines accepted by Q-language (software developed for the analyzer) were written to readjust detection levels in the programming mode and to check the identity of kernels. This check is important, as the method is based on a measurement in two orthogonal projections, and the relationship between geometrical characteristics for each kernel in both projections has a critical value. The discriminant analysis was performed with the scientific subroutine package (SAS Institute, Inc., Cary, NC).

Great care was exercised to assure proper positioning of kernels and their orientation toward the crease line (after changing the position of kernel from crease down to crease right) and to maintain the sequential count of each kernel in the set and its orientation towards the vertical axis. The kernels were placed on flat layers of black plasticine.

The following nine parameters were used in developing a pattern to discriminate between the morphological characteristics of Arthur and Arkan.

Perimeter^2/4π area = circularity shape factor (CSF) to separate circular features from others; the term feature denotes an object in the field of view, and perimeter denotes the outline (circumference) of the feature.

$2\sqrt{\text{Area}/\pi}$ = equivalent diameter (diameter of circle, having the same area as feature).

Length/breadth = aspect ratio.

Length/area.

Feret diameter = the distance between a pair of parallel tangents to the feature (feret 0, 45°, 90°, and 135°).

$V_{cone} = 1/3\ \pi \times r^2 \times h$ = volume of the assumed equivalent cone in which r = radius and h = height.

In our case r = breadth/2, h = length, and V_{cone} = 1/3 π (breadth/2)^2 × (length).

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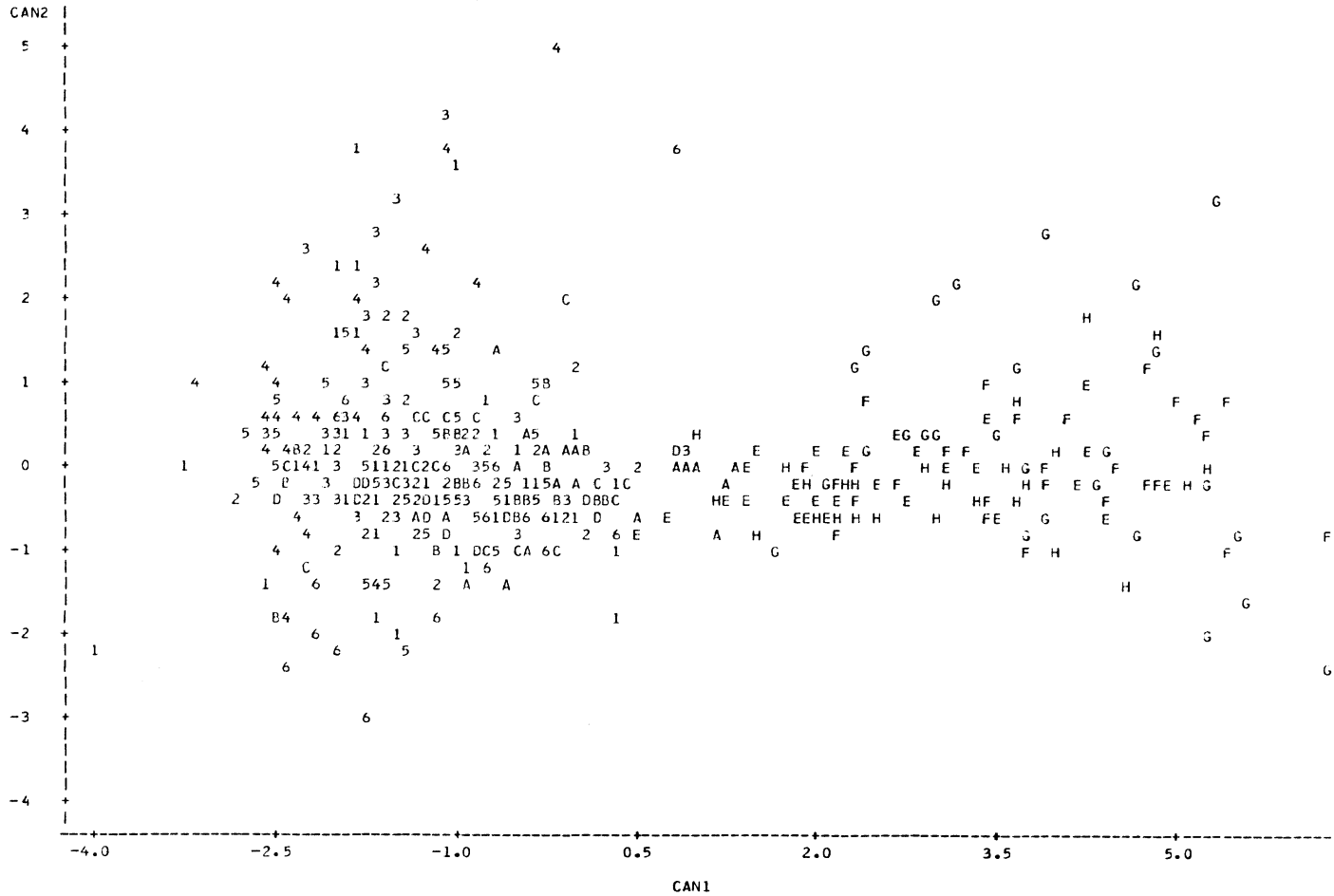

Fig. 1. Results of discrimination by image analysis between and among four Federal Grain Inspection Service samples each of Arkan (A–D) and of Arthur (E–H) and six samples from heads of Arkan (1–3 from Manhattan, KS, and 4–6 from Hutchinson, KS). Note that 94 observations are hidden because of crowding of experimental data.

$2\sqrt{\text{Area}/\pi}\,/\,\text{perimeter}/2$ = shape function to separate features by outline.

Convex perimeter = average of all ferets' diameters, an instrument-calculated function.

Q = Area/(length × breadth) = estimate of rectangularity.

A combination of these parameters from two orthogonal measurements yielded 16 variables which were used to build a discriminant function. All variables were examined and significant ones incorporated into a canonical function.

RESULTS AND DISCUSSION

A canonical function was developed to discriminate between Arthur and Arkan wheat samples from the FGIS. The function included the following nine variables; five were from differences in the two orthogonal positions and four in one position (crease down):

Differences in the Two Orthogonal Positions

Q = Estimate of rectangularity
$2\sqrt{\text{Area}/\pi}$ = equivalent diameter
Perimeter$^2/4\pi$ area = circularity shape factor
Length/breadth = aspect ratio
Projected area (instrumental determination)

As Determined with the Crease Down Position

Perimeter
Circularity shape factor
Breadth
Equivalent diameter

The results for discrimination between and among the four FGIS samples of Arkan (A–D) and Arthur (E–H) are shown in Figure 1. The canonical function discriminated, out of four samples 30 kernels each, 27, 30, 30, and 30 kernels of Arkan, and 29, 30, 30, and 29 kernels of Arthur. Thus, 235 out of 240 kernels were identified correctly. No evident clustering of kernels in the four samples of Arkan and Arthur was noted by the use of discriminant analysis. When the canonical function was used to determine the morphological features of the kernels from the six heads of Arkan wheats from Manhattan and Hutchinson, KS (identified as 1–6) the results shown in Figure 1 were obtained. The canonical function discriminated 43 out of 43, 32 out of 32, 38 out of 39, 29 out of 29, 37 out of 37, and 29 out of 29 kernels; or only one out of 209 kernels was not identified correctly. Again, no evident clustering of kernels from the six wheat heads was noted.

The discrimination between Arthur and Arkan (both for the FGIS samples and for kernels from Arkan wheat heads) was performed on mixtures that included the HRW cultivars Triumph, Newton, and Scout, and the SRW cultivars Hart and Pike (from FGIS/USDA) and the HRW cultivars Cheyenne, Vona, and Roughrider and the SRW cultivar Pike (courtesy of P. J. Mattern, U. Nebraska). Results of studies to discriminate among those wheats will be reported elsewhere. The discriminant functions developed here can be applied to any pair of named wheats, using the same parameters, but applying different calculated coefficients.

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