Short Communication

Systematic establishment of colour descriptor states through image-based phenotyping

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Abstract

A systematic method for determining colour descriptor states using image analysis is proposed using pili (*Canarium ovatum*) as a model. Kernel images of 52 pili accessions from the core collection of the Institute of Crop Science and National Plant Genetic Resources Laboratory, University of the Philippines Los Baños were captured using a calibrated VideometerLab 3 setup. Colour descriptor states were derived from the average International Commission on Illumination lightness (L*), green–red (a*) and blue–yellow (b*) colour component values. Cluster analysis and subsequent colour-parameter averaging per cluster were performed to produce representative colour values of descriptor states. The Euclidian distance (Delta E) of 3.5 was used to cut the cluster into readily distinguishable colour differences resulting to three descriptor states – light brown, brown and dark brown. Continuous colour variation of brown colour was observed indicating a possible quantitative nature of the trait. The use of delta E in elucidating the descriptor lists served as a gauge in successfully identifying distinguishable variations between colours. The method described can be applied to the elucidation of colour descriptor states of all parts of the plant of all crop species.

Keywords: *Canarium ovatum*, characterization, descriptor states, image-based phenotyping, objective colour

Introduction

Morphological characterization and the subsequent diversity assessment of plant genetic resources rely on the accuracy and precision of descriptor lists. Bioversity

International (2007) has detailed the process to develop descriptor lists; however, particularly for colour, psychophysical subjective assessment is used to discriminate the various descriptor states of the crop. With the advent of image-based phenotyping techniques, objective methods of characterizing colour may be developed, as in the case of tomato (Darrigues *et al.*, 2008) and strawberry (Yoshioka *et al.*, 2013). On the other hand, pili (*Canarium ovatum*

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Fig. 1. Pili kernel colour descriptor states of 53 accessions based on average CIE L* a* b* values. The dendrogram is cut at 3.5 Euclidian distance.

Engl.), an endemic crop in the Philippines, has no established descriptor list and use of image analysis may be useful to characterize the rich diversity of this tree species. Thus, the study aimed to systematically identify the colour descriptor states through image-based analysis using pili kernels as a model.

Experimental

Fifty-two (52) pili accessions from the core collection of the Institute of Crop Science, and the National Plant Genetic Resources Laboratory of the Institute of Plant Breeding,

College of Agriculture and Food Science, University of the Philippines Los Baños was used. Each accession was represented by 10 kernel samples as recommended by Bioversity International (2007). Images were captured using a calibrated VideometerLab 3 setup at a resolution of ~45 µm/pixel at the visible spectrum (Videometer A/S Hørsholm, Denmark). For better colour discrimination of images (Alata and Quintard, 2009), red (R), green (G) and blue (B) values per pixel were transformed to International Commission on Illumination (CIE) lightness (L*), green–red (a*) and blue–yellow (b*) values using the colour space converter plugin of ImageJ version 1.50i (Schneider *et al.*, 2012). Per sample, the pixel matrices

Table 1. Colour profiles of pili kernel colour descriptor states

Descriptor state	Description	L*	a*	b*	Hex	Colour name ^a
3	Light Brown	48.66353	13.46107	19.86509	#966A53	Leather
5	Brown	45.72803	12.91776	17.63745	#876453	Beaver
7	Dark Brown	42.65840	12.81331	15.75403	#7F5D4B	Roman Coffee

^aBased on Mehta (2001).

were separately extracted for CIE L*, a* and b* colour spaces as text images. The L*, a* and b* values per sample were averaged to get a representative colour value. From the mean values, cluster analysis was done using un-weighted pair group method with arithmetic means and sequential, agglomerative, hierarchical and nested clustering parameters program of Numerical Taxonomy and Multivariate Analysis System-pc version 2.1 (Rohlf, 2002). The dendrogram was cut at 3.5 Euclidian distance to ensure that the difference in colour is readily discernible by the observer; this was based from the Delta E value (ΔE_{Lab}) that quantifies the distinguishable differences between two colours using the CIE1976 scheme (Sharma, 2003; Mokrzycki and Tatol, 2011). The averaged CIE L* a* b* values per cluster were used to represent a descriptor state. These values were visualized, named and converted to hex formats using Name that Colour (Mehta, 2001).

Discussion

Three clusters were observed from the dendrogram cut at 3.5 Euclidian distance (Fig. 1). The three clusters represent three descriptor states for kernel colour. A varying intensity of brown colour was observed between descriptor states. Descriptor states have corresponding hex and technical colour names (Table 1); however, the description is simplified to light brown, brown and dark brown to accommodate the wide range of users, as prescribed by Bioversity International (2007).

The light brown kernel colour was dominant in the germplasm collection with 33 accessions exhibiting the colour. This was followed by brown with 17 accessions. The dark brown coloured accessions, however, were only represented by two accessions indicating a gap in the diversity of the observed collection. It can also be observed that all accessions have varying average CIE L* a* and b* values which denote a degree of heterogeneity of colours within the cluster; however, the variations may result in non-perceivable differences due to low delta E values (Witzel *et al.*, 1973; Mokrzycki and Tatol, 2011). Cutting the cluster at a higher delta E of 3.5 will allow inexperienced observers to distinguish the colour variations (Mokrzycki and Tatol, 2011) in adherence to the standards of Bioversity International (2007). Furthermore, colour differences may

be controlled by quantitative trait loci, such as in the case of the seed coat colour of chickpea (Hossain *et al.*, 2011) and endosperm colour of sorghum grain (Fernandez *et al.*, 2008), resulting in the continuous variation of brown colour in the accessions. Rather than viewing pili kernel colour as a discrete qualitative trait, the continuous variation in the intensity of brown colour may have a quantitative nature. Despite this, colour descriptor states, whether quantitative or qualitative in nature, are still vital in representing trait variations in the germplasm collection. On the other hand, charts and visuals of standards should be provided in order to distinguish continuous colour variations such as in the case of pili. Hex and CIE L*a*b* values, together with the technical colour name, may also be provided for reference.

Although pili was used as a model, the systematic method of establishing colour descriptor states can be applied to all homogenously-coloured parts of the plant of all crop species. It is also recommended to use a dynamic tree cut method in resolving clusters to ensure equal magnitudes of variations between clusters.

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