Digital Image Analysis of Sweetpotato Storage Roots in Herbicide Trials

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Abstract. Digital image analysis (DIA) was evaluated for use in assessing size and shape attributes of sweetpotato [*Ipomoea batatas* (L.) Lam.] storage roots in herbicide studies. Digital image files of U.S. no. 1 storage roots were taken using a digital camera. Image analysis was performed using a publicly available software package. Eight size and shape attributes were measured and subjected to univariate and multivariate procedures. DIA revealed differences for storage root width and roundness attributes. Principal component analysis suggested that storage root length, width, and roundness best described the variability of the storage root sample. The results demonstrate the potential use of DIA in augmenting data from sweetpotato herbicide trials as well as other investigations that require information about storage root size and shape responses.

Previous sweetpotato herbicide studies evaluated treatment effects on crop vigor and yield, but limited information was gathered about storage root morphological responses (Harrison and Dukes, 1996; Harrison et al., 1985; Motsenbocker and Monaco, 1993). Currently, there is no known published method that routinely assesses sweetpotato storage root size and shape attributes. Such a method will potentially detect possible herbicide effects on storage roots that are not measurable using current visually based procedures or grading methods.

Digital image analysis (DIA) has become an important tool in the quantification of plant characters, especially those that require tedious measurements. In particular, DIA has been routinely used to measure plant root attributes like length, diameter, width, and area (Iwata et al., 1998; Lebowitz, 1988; Tagliavini et al., 1993). This study evaluates the feasibility of digitally assessing size and shape attributes in sweetpotato storage roots, in particular those obtained from herbicide studies.

U.S. no. 1 (5.1–8.9 cm diameter, 7.6–22.9 cm long) 'Beauregard' sweetpotato storage root samples were obtained from the 2000 herbicide study at the Sweet Potato Research Station in Chase, La. The treatments are summarized in Table 1. Sample number ranged from 15 to 30 per treatment for a total of 420. A grading board was used to ensure that the specifications for the U.S. no. 1 grade were strictly met. Digital images (jpeg format) of

storage roots against a black background were taken using a light stand-mounted Olympus D-360 L camera (Olympus, Tokyo) at a resolution of 640×480 pixels. Five to eight samples were accommodated per image. A metric scale was included in all images to facilitate calibration. The files were imported into Image Tool Version 2 (Univ. of Texas Health Science Center at San Antonio, available from ftp://maxrad6.uthscsa.edu) and processed using the following steps: conversion into grayscale images, manual thresholding, calibration, object identification, and object analysis.

Table 1. Effects of various weed control treatments on selected sweetpotato storage root digital image attributes as measured by Image Tool.²

Herbicide		Application rate (kg·ha ⁻¹ a.i.)	Attribute ^y	
			MINAX	ROUND
Fomesafen	Reflex 2LC, Zeneca, Richmond, CA	0.55	5.961	0.295
Thiazopyr	Visor 2E, Rohm and Haas, Philadelphia, PA	0.27	5.920	0.265
Hand-weeded			5.790	0.285
Metolachlor	Dual Magnum, Novartis, Greensboro, NC	1.12	5.748	0.359
Metribuzin				
+ Clomazone	Sencor DF, Bayer + Command 3ME, FMC	1.12 + 1.16	5.719	0.287
EPTC				
+ Clomazone	Eptam 7E, Zeneca + Command 3ME, FMC	3.34 + 0.58	5.659	0.299
Metolachlor	Dual Magnum, Novartis, Greensboro, NC	2.24	5.633	0.308
Dimethenamid	Frontier 6, BASF, Research Triangle, NC	1.32	5.503	0.272
Thiazopyr	Visor 2E, Rohm and Haas, Philadelphia, PA	0.55	5.493	0.295
Dimethenamid	Frontier 6, BASF, Research Triangle, NC	0.66	5.478	0.284
Metribuzin				
+ Clomazone	Sencor DF, Bayer + Command 3ME, FMC	1.12 + 0.56	5.423	0.324
EPTC	Eptam 7E, Zeneca, Richmond, CA	3.34	5.397	0.279
Fomesafen	Reflex 2LC, Zeneca, Richmond, CA	0.27	5.381	0.283
EPTC				
+ Clomazone	Eptam 7E, Zeneca + Command 3ME, FMC	3.34 + 1.16	5.353	0.327
Clomazone	Command 3ME, FMC, Philadelphia, PA	0.58	5.312	0.322
Not weeded			5.312	0.288
EPTC	Eptam 7E, Zeneca, Richmond, CA	6.68	5.290	0.287
P value			0.03	0.05
LSD _{0.05}			0.468	0.051
CV (%)			14.78	30.28

²UTHSCSA Image Tool program Version 2 (developed at the Univ. of Texas Health Science Center at San Antonio, Texas, and available from the Internet by anonymous FTP from ftp://maxrad6.uthscsa.edu).

³MINAX = the length of the longest line that can be drawn through the object perpendicular to the major axis. ROUND = (4 × PI × area)/perimeter. 1 = object is more round.

Thresholding was considered optimum when pixel allocation unambiguously differentiated sample objects from a dark background. The object analysis phase measured eight attributes or variables (Table 2). AREA, PERIM, MAXIS, and FDIA were square root-transformed prior to analysis to satisfy normality assumptions. Data were separately analyzed using both univariate and multivariate procedures. First, ANOVAs were performed for each variable using SAS PROC GLM (SAS Institute, Cary, N.C.). Subsequently, principal component analysis (PCA) was performed using SAS PROC PRINCOMP (correlation matrix) to identify: 1) the number of principal components using the cumulative proportion of total variance, and 2) a subset of variables that best described variability in the data set.

Although the storage root sample was strictly graded, DIA revealed significant differences for MINAX ($P=0.03$, Table 1), a size attribute, and ROUND ($P=0.05$, Table 1), a shape attribute that is pose (location, orientation, and size) invariant (Glasbey and Horgan, 1995). Even though the current study does not identify the specific cause of these observed differences, DIA can be used in future studies to assist in the identification of the specific cause of size and shape differences. Using the multivariate data analysis approach, PCA revealed that the first three principal components accounted for 97% of the total observed variability. From a multivariate analysis point of view, MAXIS, MINAX, and ROUND will best describe size and shape variation of the storage root sample based on the examination of the eigenvector elements (Khattree and Naik, 2000).

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Table 2. Description of object attributes that were measured by Image Tool.^z

Attribute ^y	Description
Area (AREA)	The area of the object.
Perimeter (PERIM)	The length of the outside boundary of the object.
Roundness (ROUND)	$(4 \times \text{PI} \times \text{area}) / \text{perimeter}^2$. 1 = object is more round
Elongation (ELONG)	MINAX:MAXIS ratio. As ratio decreases from 1, object becomes more elongated.
Feret diameter (FDIAM)	$\sqrt{4 \times \text{area} / \text{PI}}$. The diameter of a circle having the same area as the object.
Compactness (COMPA)	$\sqrt{4 \times \text{area} / \text{PI} / \text{MAXIS}}$. 1 = roughly circular object.
Major axis length (MAXIS)	The length of the longest line that can be drawn through the object.
Minor axis length (MINAX)	The length of the longest line that can be drawn through the object perpendicular to MAXIS.

^zUTHSCSA Image Tool program Version 2 (developed at the Univ. of Texas Health Science Center at San Antonio, Texas, and available from the Internet by anonymous FTP from <ftp://maxrad6.uthscsa.edu>). Description of the object attributes obtained from accompanying software documentation.

^yAll measurement units in unit of calibration, i.e., cm. PI = 3.1416.

The results illustrate the potential for DIA to enhance information from herbicide studies as well as other investigations that require data about sweetpotato storage root size and shape responses. For example, DIA can be used as a tool to quantify storage root shape for breeding purposes. To assess its robustness, it is necessary to further evaluate this procedure under various experimental conditions and growing environments.

Literature Cited

- Glasbey, C.A. and G.W. Horgan. 1995. Image analysis for the biological sciences. Wiley, New York.
- Harrison, H.F., Jr., and P.D. Dukes. 1996. Sensitivity of four sweetpotato clones to metribuzin herbicide. *HortScience* 31:846–847.
- Harrison, H.F. Jr., A. Jones, and P.D. Dukes. 1985. Differential response of six sweet potato (*Ipomoea batatas*) cultivars to metribuzin. *Weed Sci.* 33:730–733.
- Iwata, H., S. Niikura, S. Matsuura, Y. Takano, and Y. Ukai. 1998. Evaluation of variation of root shape of Japanese radish (*Raphanus sativus* L.) based on image analysis using elliptic Fourier descriptors. *Euphytica* 102:143–149.
- Khattree, R. and D.N. Naik. 2000. Multivariate data reduction and discrimination with SAS software. SAS Inst., Cary, N.C.
- Lebowitz, R.J. 1988. Digital image analysis measurement of root length and diameter. *Environ. Expt. Bot.* 28:267–273.
- Motsenbocker, C.E. and T.J. Monaco. 1993. Differential tolerance of sweet potato (*Ipomoea batatas*) clones to metribuzin. *Weed Tech.* 7:349–354.
- Tagliavini, M., L.J. Veto, and N.E. Looney. 1993. Measuring root surface area and mean root diameter of peach seedlings by digital image analysis. *HortScience* 28:1129–1130.