IbRootNet: A Collaborative Platform for Distributed Sweetpotato Root Architecture Phenotyping for Enhanced Crop Improvement and Management

Edward E. Carey[1], Maria Andrade[2], Rebecca Sweany[3], Christopher Clark[3], Arthur Villordon[4]

[1]International Potato Center (CIP), c/o CSIR-CRI, P.O. Box 3785, Kumasi, Ghana, [1]International Potato Center (CIP), c/o IIAM, Maputo, Mozambique,
[3]LSU AgCenter Department of Plant Pathology and Crop Physiology, Baton Rouge, LA 70803, U.S.A., [4]LSU AgCenter Sweet Potato Research Station, Chase , LA 71324, U.S.A.

Summary

In model systems, e.g., Arabidopsis, Zea mays, and Oryza sativa, significant progress has been made in root system architecture (RSA) research. It has been demonstrated in these model systems that the understanding of the internal and external variables that influence RSA has led to the advancement of fundamental knowledge and the development of practical applications such as varieties with enhanced tolerance to drought and nutrient deficiency. In sweetpotatoes, the understanding of the internal and external variables that influence RSA is even more important because the storage roots are derived from adventitious roots that arise during the establishment of the plant. There is an emerging interest in understanding the role of adventitious root architecture in storage root formation and how this knowledge can be harnessed for enhancing crop improvement and management strategies. However, the current capacity for sweetpotato RSA analysis is hampered due to the lack of expertise and equipment in many locations where sweetpotato research and development is ongoing. IbRootNet is an informatl collaboration among researchers from CIP locations in Ghana and Mozambique as well as LSU AgCenter's Sweet Potato Research Station and Department of Plant Pathology and Crop Physiology. The main purpose of this collaboration is to develop and validate tools and methodologies for characterizing and describing the genotypic variation in sweetpotato RSA. A secondary objective is to identify RSA variability in response to biotic and abiotic factors including but not limited to virus, nutrient deficiency and drought. We will present a case study involving the collaborative analysis of the RSA of 25 Sub-Saharan sweetpotato genotypes. The advantages and disadvantages of the distributed analysis approach will be discussed.

What is root architecture?

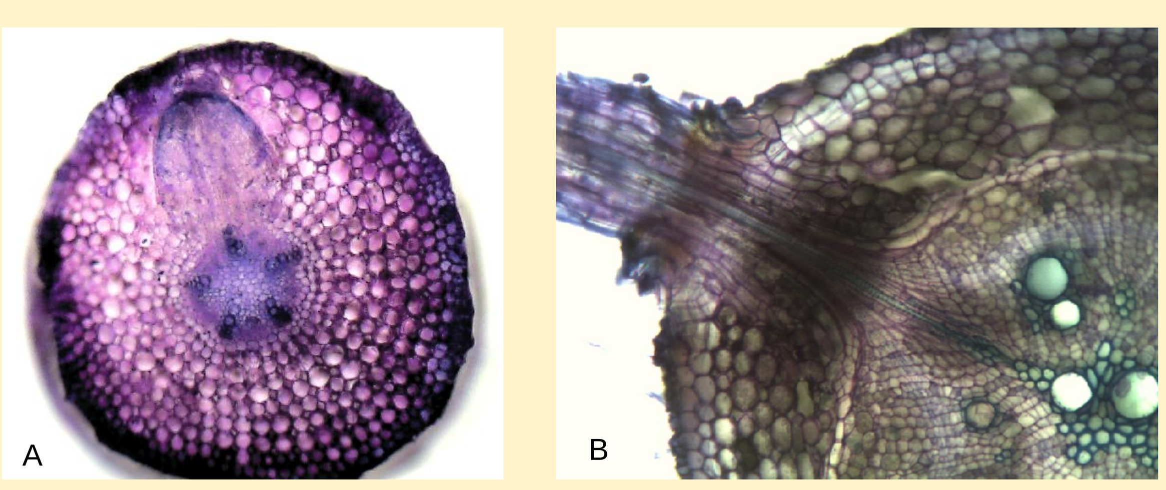

Figure 1. Lateral root initiation begins in sweetpotato adventitious roots within 24 hours of adventitious root appearance (A), then connects to the main root and grows (B).

Nutrients and water are unevenly distributed in natural and agricultural soils so that the spatial deployment of the root system helps to determine the ability of a plant to exploit these resources. The spatial configuration of the root system is extremely plastic and lateral root development is among the major processes that help to shape root system architecture (Babe et al., 2012). Root system architecture has been referred to as an integrative results of lateral root (LR) initiation, morphogenesis, emergence, and growth (Dubrovsky and Forde, 2012). RSA explicitly incorporates a spatial context, i.e., the explicit geometric deployment of root axes (Lynch, 1995). In sweetpotatoes, LRs originate from the pericycle opposite the protoxylem pole (Fig. 1a). The timing of this process occurs within a day after an adventitious root appears. The lateral root primordium becomes meristematic prior to emergence and forms vascular connections with the main root (Fig. 1b). This process occurs only if the external conditions are favorable, including the availability of moisture and nitrogen. Around the time of storage root formation, lateral root development is optimum (Fig 2a). Lateral root scars are frequently visible on enlarged storage roots (Fig. 2b).

Figure 2. Lateral root development on a storage root at an early bulking stage (A). Lateral root scars are frequently visible on enlarged storage roots (B).

Experimental Methods

Figure 3. Pathogen-tested elite sweetpotato genotypes in the screenhouse at CSIR-CRI prior to collection of root samples.

- Genotypes were grown in potting media (sand:loam:manure; 2:1:1)
- Plants were harvested at 21 days after planting
- Soil moisture was not monitored but was often excessive due to rain

Table 1. Descriptions of selected genotypes used in the study.

Genotype	Origin	Description
1. Mugande	Farmers' variety Rwanda	Released in Ghana, dual purpose variety
2. Jane	Mozambique (LO323-1)	OFSP
3. Cemsa 74-228	Cuban bred variety	Released in Ghana
4. Vitaa	Uganda (SPK004/6)	OFSP Released in Kenya, Uganda
5. Melinda	Mozambique (W119-15)	
6. Ejumula	Farmers' variety Uganda	Released in Uganda, Mozambique
7. Bela	Mozambique (UW11906-79)	OFSP
8. Ningshu 1	China	"Megaclone"
9. Mugamba	Farmers' variety Burundi	Released in Ghana
11. Amelia	Mozambique (Maphutha-1)	OFSP
21. Ininda	Mozambique (Tacna-2)	OFSP
24.Kabode	Uganda (SPK004/6/6)	OFSP
25. 199062.1	CIP-HQ	Light OFSP

Figure 4. Sample processing. At 21 days, near intact root systems were collected from each plant by removing the growth substrate with a stream of water (A). The roots were floated on waterproof trays and scanned.

The images were uploaded to a Dropbox to facilitate downloading and viewing by collaborators. The images were analyzed in Chase, LA, U.S.A. and the results were forwarded to all collaborators.

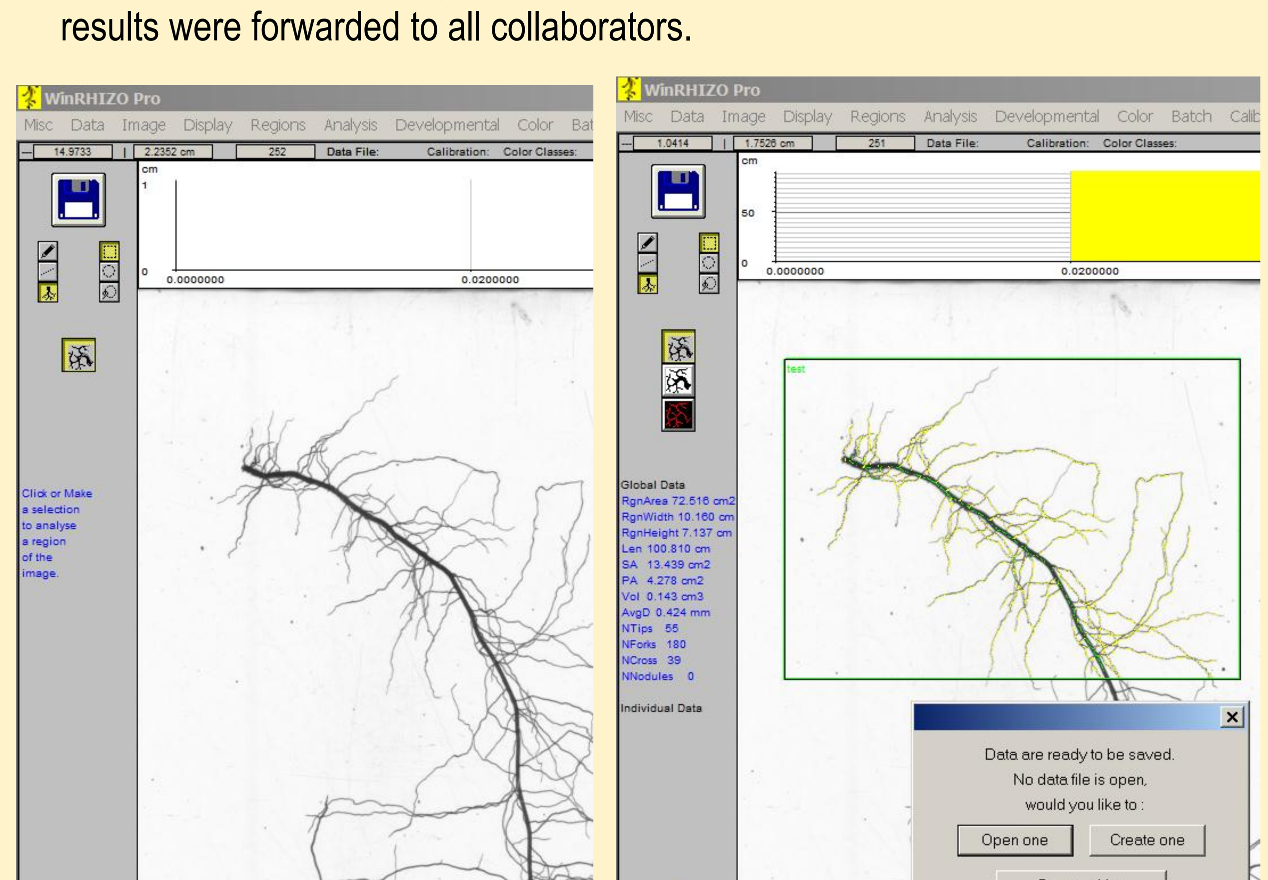

Figure 5. Screen capture of WinRhizo image analysis software showing a scan of an adventitious root sample (A) and after image analysis (B).

Some of the genotypes showed delayed adventitious root growth relative to other genotypes. These were excluded from the analysis. To adjust for differences in main root lengths, only the proximal 10 cm of each sample was scanned and analyzed. The results of the preliminary analysis are shown in Figure 6. The preliminary data revealed a wide range of variability for key root architecture traits that have been showed to be associated with storage root formation, i.e., LR length and density. Storage root formation at 20 days was verified by the presence of anomalous cambia in adventitious root sections that manifested increased lateral root density.

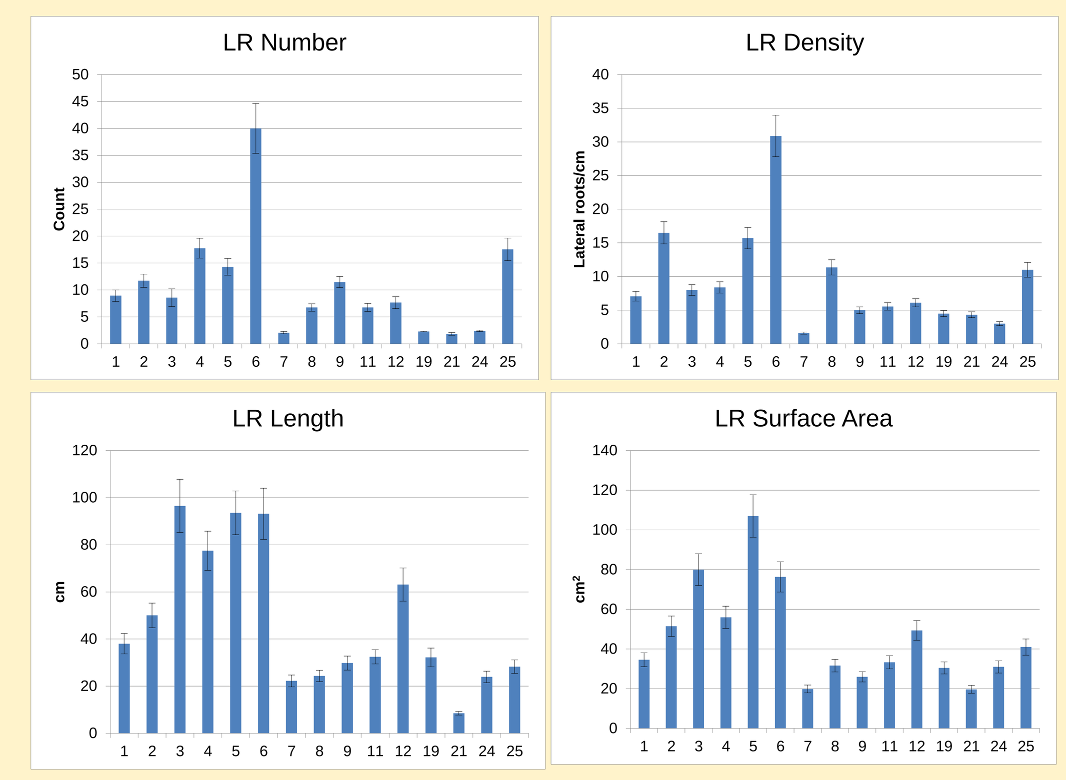

Figure 6. Lateral root attributes of sweetpotato genotypes from SSA.

These results indicate significant variation among genotypes in response to the environmental conditions they were exposed to during the experiment. For example, Ejumula appeared to be very tolerant of excess moisture combined with high soil N, conditions that lead to failure of storage root formation and excessive partitioning to foliage in many genotypes. High lateral root number, density and length are all indicators of successful storage root initiation and predict likely development and yield. However almost all work to date has been done with one genotype, Beauregard (Villordon et al, 2013).

Future efforts will:

- Repeat the experiment with identity-verified genotypes
- Determine frequency and rates of adventitious root development by genotype in order to ensure comparable results among genotypes
- Assess relationship between RSA attributes in pot studies and field performance with respect to storage root initiation and development
- Permit prediction of response of individual genotypes to moisture, fertility, biology and other management practices including use of virus-free planting material
- Assist with the selection of genotypes with preferred attributes such as RSA for efficient utilization of nutrients such as P

Collaboration and complementarity of efforts partners will effectively utilize resources of individual projects in support of global sweetpotato improvement objectives in the service of humanity and the environment.

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