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A FIELD MACHINE FOR AUTOMATED QUANTIFICATION OF SWEET POTATO PHENOTYPIC TRAITS

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Abstract

Sweet potato is a globally important food crop, and its breeding is essential for enhancing nutritional value, ensuring food security, and promoting sustainable agriculture. However, the current process of parental selection largely depends on manual visual assessment, which is time-consuming and subject to human bias, thereby limiting both the efficiency and accuracy of breeding programs. In this work, a field machine for automated quantification of sweet potato phenotypic traits was proposed and developed. This field machine integrated an industrial camera, YOLOv7 deep learning model, and Mask R-CNN segmentation for automated quantification of sweet potato root traits, including length, width, and morphological characteristics. This system allows users to capture field images by simply pushing the device to a target location and pressing a button. A scalebar integrated into the system enables the conversion of image pixels into real-world dimensions. The developed sweet potato detection model achieved a precision of 92% and a recall of 93%. The Mask R-CNN model accurately extracted root contours, facilitating precise morphological measurements. This integrated workflow significantly reduces manual labor while enhancing the consistency and throughput of phenotypic data collection. The developed system provides a standardized, automated solution for sweet potato parental selection and offers a promising tool for large-scale field trials. It contributes to the advancement of data-driven breeding strategies and supports the broader transition toward intelligent and sustainable agriculture.

Keywords: Object detection, Instance segmentation, YOLOv7, Mask R-CNN, Agricultural computer vision

INTRODUCTION

Global population growth and climate change intensify food security challenges, with FAO projecting a 70% increase in food demand by 2050. Sweet potato, cultivated on 7.41 million hectares worldwide and valued at 24 billion NTD in Taiwan, still relies on subjective visual breeding. This study developed an automated phenotyping system for real-time root measurement, offering an efficient, objective tool to accelerate genetic improvement and support smart agriculture.

MATERIALS AND METHODS

A field-deployable mobile platform was developed for in situ sweet potato phenotyping (Fig. 1), integrating a high-resolution webcam and Jetson Nano for real-time imaging and processing. A shading enclosure with dual-sided LED lighting ensured standardized conditions (Fig. 2). ArUco markers were used as reference scales (Fig. 3), enabling pixel-to-scale calibration and accurate real-size measurement of root length, width, and area (Fig. 4).



Fig.1 A field-deployable mobile platform

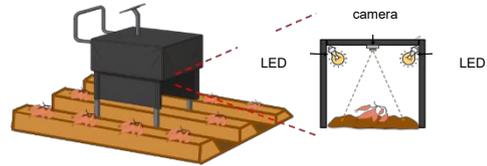


Fig.2 Experimental framework

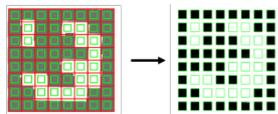


Fig.3 Grid classification and binary decoding



Fig.4 Real-size output

RESULTS & DISCUSSION

The phenotyping system was tested with YOLOv7 and YOLOv11 combined with YOLO segmentation and ArUco markers. YOLOv11 outperformed YOLOv7, especially for small or occluded roots (Table 1). With ArUco calibration, measurement errors for length and width were within ± 1 cm, reducing manual error and accelerating field phenotyping (Table 2).

Table 1 YOLOv7 vs. YOLOv11

Model	Precision	Recall	mAP@0.5	mAP@0.5:0.95
YOLOv7	0.923	0.934	0.987	0.883
YOLOv11	0.961	0.972	0.990	0.895

Table 2 Real-size measurement results

Image No.	ID	Area (pixel)	Length (cm)	Width (cm)
1	1	31248	11.88	5.76
	2	33909	12.67	5.93
2	1	28028	8.56	7.28
	2	32718	12.58	5.79
Error range : 0.5~1cm				

CONCLUSIONS

This study developed a sweet potato phenotyping system integrating YOLO detection, segmentation, and ArUco calibration for automated field data collection. The system reduced bias and improved efficiency by keeping measurement errors within ± 1 cm, and YOLOv11 was selected as the primary detection model for its superior performance.

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