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EVALUATION OF PLANTING ACCURACY AND EARLY GROWTH UNIFORMITY OF SPRING CABBAGE IN GREENHOUSES

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Abstract

Mechanized transplanting reduces labor and time in greenhouse cabbage production, yet misplacement, over burial, and missing seedlings still compromise uniform stands This study evaluated transplant quality and early growth uniformity with two stages during transplanting and harvesting image and machine learning workflow at plot scale. Two transplanters, automatic and semi-automatic, were tested under ridge widths of 60, 70 and 80 cm and seedling ages of 30 and 35 days. In February after transplanting, UAV and handheld images were used to detect missing, tilted, and buried seedlings and to measure spacing and row alignment errors. In April during early head formation, UAV RGB images were segmented with a U Net to outline canopies. Plot summaries included plant count, canopy area, equivalent diameter in pixels and coefficient of variation of canopy size. Ground based data collection included head diameter, circumference, fresh weight and root weight. Automatic transplanting with 35-day seedlings produced fewer errors and lower canopy variation. Image based canopy metrics matched field diameter and circumference, while links to weight and root traits were weaker. A ResNet classifier distinguished normal, tilted, buried, and missing seedlings with about 90% accuracy, and an XGBoost regressor explained approximately 65% of variation in canopy uniformity. The combined pipeline enables efficient transplant auditing, uniformity mapping, and treatment comparison with low field burden. Incorporating scale markers or stereo and multi-view imagery would further enhance absolute canopy estimation and strengthen links to yield traits.

Keywords: Mechanized transplanting, precision agriculture, growth uniformity, planting error detection, machine learning, greenhouse

INTRODUCTION

Uniform transplanting is essential for cabbage yield, yet placement errors reduce stand quality. In addition, mechanized transplanters reduce labor but must ensure precise spacing and depth. Variations in ridge width and seedling age add complexity in greenhouses. The objective was to assess how machine type, ridge width and seedling age affect errors and early canopy development using UAV imagery, ground traits and machine learning.

MATERIALS AND METHODS

The experiment was conducted in February and April with automatic and semi-automatic transplanters, ridge widths of 60, 70 and 80 cm and seedling ages of 30 and 35 days. In February, UAV nadir and handheld images and videos after transplanting collected plot error metrics for missing, tilted, buried, spacing and alignment. In April, UAV RGB images segmented with a U Net collected plant count, canopy area, equivalent diameter and coefficient of variation. Masks were checked to avoid segmentation errors. Ground based data collection included head diameter, circumference, fresh weight, and root weight. A ResNet classifier labeled seedlings as normal, tilted, buried or missing. An XGBoost regressor predicted canopy coefficient of variation using machine type, ridge width, seedling age and error metrics. Analysis of variance tested treatment effects and correlations were calculated at plot level.

RESULTS & DISCUSSION

The automatic transplanter produced fewer missing and tilted seedlings than the semi-automatic unit, and 35-day seedlings were more uniform than 30-day seedlings. Missing rates declined from about 10% at 30 days to 5% at 35 days with the automatic machine, and wider ridges reduced spacing and alignment errors. These differences were statistically significant across treatments, and plots with fewer errors showed lower canopy variation, confirming more uniform early growth. Image-derived canopy diameter and area were strongly aligned with head diameter and circumference, while links to weight and root traits were modest due to the lack of scale and the influence of plant structure. Machine learning reinforced these findings. A ResNet classifier applied to February imagery separated seedling classes with accuracy near 90%. An XGBoost regressor explained about 65% of variance in canopy uniformity using machine, ridge, age, and error metrics. Together, field-based auditing and model outputs demonstrate that automatic transplanting with older seedlings improves establishment and that machine learning supports rapid error detection and forecasting of uniformity.

CONCLUSIONS

Transplant-error showed robust plot-scale indicators sensitive to machine type, ridge width, and seedling age. Canopy diameter and area aligned with head diameter and circumference, while associations to fresh weight and root traits remained limited under current constraints. The approach is immediately deployable for transplant quality control and early uniformity assessment. Future research using scale targets, stereo or multi-view imaging, and ortho-rectified mosaics is expected to strengthen absolute size estimation and to tighten the linkage between image-based descriptors and yield outcomes.

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