Stage-Wise Field Observation Framework for Early Mango Yield Estimation

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Abstract: Mango (*Mangifera indica*) is one of the most important fruit crops cultivated in tropical and subtropical regions. Accurate yield estimation is essential for harvest planning, supply-chain management, and orchard decision-making. Conventional yield estimation practices primarily rely on manual observations, which are often labor-intensive and subject to observer variability. Recent advances in computer vision and remote sensing have created opportunities for data-driven yield forecasting; however, the availability of structured field datasets representing flowering and early fruit development stages remains limited. This study presents a stage-wise field observation framework for early mango yield estimation based on systematic image acquisition across multiple phenological stages. A longitudinal dataset was developed using 25 mango trees monitored from four viewing directions at weekly intervals. The framework incorporates image acquisition, quality verification, preprocessing, stage annotation, and dataset organization procedures. The resulting dataset captures flowering progression and early fruit development under real orchard conditions. The framework establishes a foundation for future yield estimation studies and contributes a structured methodology for collecting temporal phenological information in mango orchards. The proposed approach may support future research in crop monitoring, phenological assessment, and early-season yield forecasting.

Keywords: Mango Yield Estimation; Phenology; Flowering Progression; Dataset Development; Orchard Monitoring

Introduction

Mango (*Mangifera indica*) is widely cultivated across Asia, Africa, and Latin America and contributes significantly to agricultural economies. In India, mango cultivation occupies a substantial area and serves as a major source of income for farmers and exporters. Reliable yield estimation is therefore important for production planning, market forecasting, storage management, and transportation logistics.

Traditional yield estimation methods are typically based on manual counting, flowering assessment, and expert judgment. Although widely adopted, these approaches are time-consuming and often affected by environmental conditions and observer experience. Consequently, researchers have increasingly explored computer vision, remote sensing, and machine learning techniques to support agricultural monitoring and yield forecasting [1]–[4].

Flowering represents a critical stage in mango production because it directly influences fruit set and final yield. Studies have reported promising results in flower detection [1], flowering intensity assessment [6], panicle stage classification [5], and orchard monitoring using aerial imagery [8], [9]. However, most existing studies focus on either flowering assessment or yield prediction independently. Limited attention has been given to structured field observations that systematically capture flowering progression and early fruit development over time. The development of longitudinal datasets is essential for understanding phenological changes and supporting future yield estimation models. Therefore, this study proposes a stage-wise field observation framework designed to collect and organize temporal orchard data for early mango yield estimation.

Related work

The use of computer vision in agricultural monitoring has expanded considerably during recent years. Kumar and Patel [1] demonstrated the effectiveness of deep learning techniques for detecting and classifying mango flowers and buds. Similarly, Patel et al. [6] employed computer vision methods to estimate flowering intensity and reported strong consistency with manual observations.

Phenological monitoring has also received attention in mango research. Sharma et al. [5] investigated deep learning approaches for classifying mango panicle development stages, highlighting the importance of stage identification for orchard management. Chopra et al. [7] further demonstrated the applicability of machine vision techniques for flowering assessment in orchard environments.

In addition to image-based approaches, remote sensing technologies have been explored for yield prediction. Torgbor et al. [4] integrated weather information and remote sensing variables for mango yield forecasting. UAV-based orchard monitoring frameworks have also been investigated by Ali et al. [8] and Faye et al. [9].

Although these studies have contributed significantly to flowering assessment and yield prediction, the availability of structured longitudinal datasets capturing flowering progression and early fruit development remains limited.

Table 1. Compares this work with the related work or previous research by other researchers

Study	**Flowering Assessment**	**Temporal Monitoring**	**Yield-Oriented Dataset**
Kumar and Patel [1]	Yes	No	No
Sharma et al. [5]	Yes	Limited	No
Patel et al. [6]	Yes	No	No
Torgbor et al. [4]	Indirect	Yes	Yes
Ali et al. [8]	Indirect	Yes	Yes
Present Framework	Yes	Yes	Yes

The review indicates a need for structured datasets that systematically capture flowering progression and support future yield estimation studies.

Framework Contribution

The framework developed in this study contributes to the existing body of knowledge through:

1. A structured protocol for stage-wise field observation in mango orchards.
2. Multi-directional image acquisition to reduce viewpoint dependency.
3. Longitudinal monitoring of flowering and early fruit development stages.
4. Standardized dataset organization and annotation procedures.

5. A reusable foundation for future yield estimation and phenological studies.

Unlike existing approaches that primarily focus on flower detection or remote sensing analysis, the proposed framework emphasizes systematic field-level data collection and stage-wise observation.

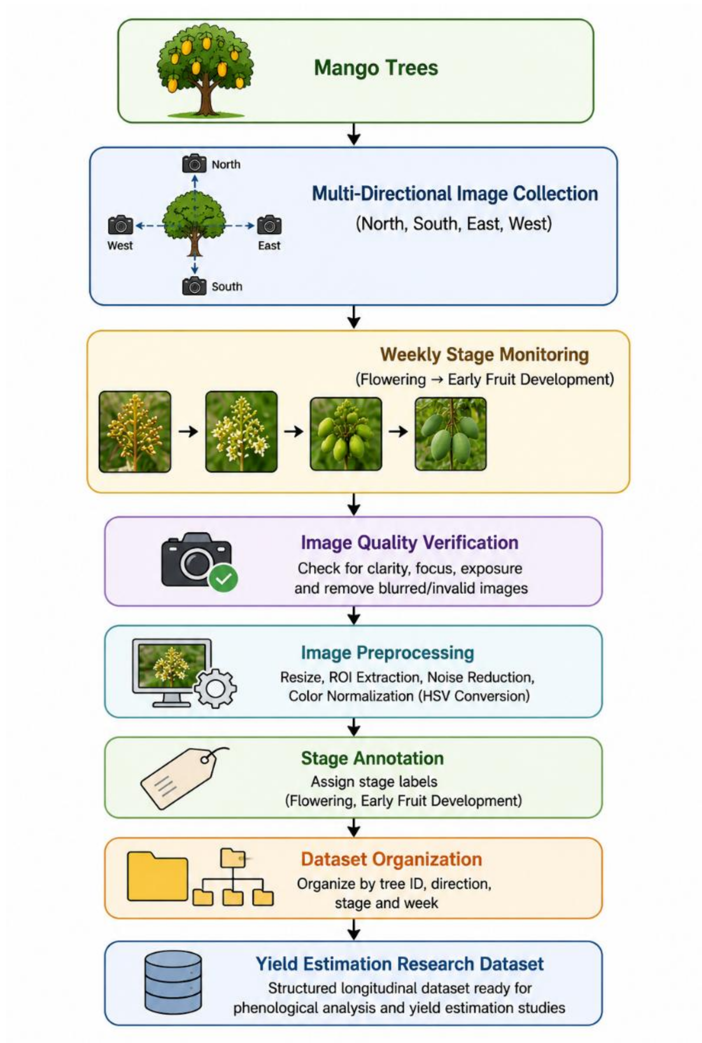
Methodology

Study Design

A field observation protocol was developed to monitor flowering progression and early fruit development under orchard conditions. The framework was designed to capture temporal changes while maintaining consistency across image acquisition sessions.

The workflow adopted in this study is presented in Figure 1.

Figure 1. Stage-wise field observation framework for mango yield estimation.



Dataset Collection Protocol

Data collection was conducted using selected mango trees monitored at regular intervals. Images were acquired from four viewing directions to capture variations in canopy structure and flowering distribution.

Table 2. Dataset Collection Design

Parameter	Description
Number of Trees	25
Viewing Directions	North, South, East, West
Observation Frequency	Weekly
Growth Stages	Flowering and Early Fruit Development
Images per Stage	100
Total Images	200

Image Acquisition

Images were collected using field-based photography under natural orchard conditions. The acquisition process followed a consistent protocol to minimize variation caused by camera positioning and viewing angle.

Multi-directional image acquisition was adopted because flowering intensity may vary across different sides of the canopy. Capturing images from multiple directions therefore provides a more comprehensive representation of tree conditions.

Data Preparation

Following acquisition, images underwent a quality verification process to remove blurred or unsuitable samples. The retained images were subsequently organized according to observation stage and collection period.

Preprocessing procedures included:

- Image resizing
- Noise reduction
- Canopy-focused region extraction
- Color normalization
- Stage labeling

The resulting dataset was organized to support future temporal analysis and yield estimation studies.

Observations and Discussion

The collected images revealed clear visual differences between flowering and early fruit development stages. Flowering stages exhibited dense floral clusters and prominent color patterns, whereas early fruit development stages displayed increased structural variation associated with fruit emergence.

The longitudinal collection strategy enabled observation of phenological progression over time. Such progression is difficult to capture through single-time-point datasets and may provide useful information for future yield estimation studies.

The framework also demonstrated the practicality of field-based image acquisition for orchard monitoring. Compared with UAV or satellite-based approaches [4], [8], [9], ground-level observations offer a cost-effective alternative while preserving detailed visual information.

Furthermore, multi-directional imaging reduced dependence on a single viewing angle and improved representation of canopy characteristics. This may be beneficial for future studies investigating relationships between flowering progression and final yield.
The developed dataset therefore provides a structured resource for future research in phenology, crop monitoring, and yield estimation.

Conclusions

1. A stage-wise field observation framework was developed for monitoring mango flowering progression and early fruit development.
2. The framework incorporates multi-directional image acquisition, temporal monitoring, and standardized dataset organization.
3. A longitudinal dataset consisting of flowering and fruit development observations was successfully established.
4. The collected observations indicate that stage-wise phenological information may support future yield estimation studies.
5. Future work will focus on expanding the dataset, incorporating environmental variables, and evaluating predictive models for early mango yield estimation.

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