Temporal Analysis of Multi-Stage Flowering Progression for Mango Yield Forecasting

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Abstract: Mango yield estimations are essential aspects in the management of orchards as they help with crop management and agricultural planning. Traditional yield estimation approaches rely on manual observations in the field, which consume a lot of time and effort and can give varying results depending on the person performing the crop observation. Recent works have shown the efficiency of using computer vision, remote sensing, and data-based techniques in agricultural observations, but not much attention has been paid to the investigation of how the process of flowering at different stages may help with yield forecasting. The research deals with the study of the flowering process using field research data received through sequential observations in the field of mango tree plantations. The research uses a solid approach to the collection of images. The researchers took pictures of 25 mango trees from four different angles and at five stages of the flowering process. After the collection of the images, they carried out the procedure of digital processing of the images. Primary results demonstrate that flowering process has a recognizable possibility in order to analyze the process of flowering transition into fruit. Thus, the new research has helped create a pattern for the analysis of flower formation in its transformation into mango fruits.

Keywords: Mango Yield Forecasting; Phenology; Flowering Progression; Temporal Analysis; Orchard Monitoring

Introduction

The mango fruit (Mangifera indica) is among the most crucial fruit crops produced in tropical and subtropical areas. Yield estimation is an important process from different perspectives, including the management of orchards, harvest planning, and market forecasting. The ability to predict yields helps farmers use resources efficiently and make the better decisions during the crop production process. Conventional methods for estimating yields rely on different manual techniques, including flowering intensity measurement, counting the number of fruits, and expert opinion [1]-[4]. The drawback of these methods resides in their subjectivity and limited applicability. The developments in computer vision and remote sensing technologies have led to the emergence of modern ways of predicting yield [1]. Flowering is an important stage of developing mangoes and one of the crucial steps influencing the process of final fruit production. There is some information about flowering detection [1], estimation of flowering intensity [6], determination of panicles stages [5] and remote-sensing-based yield prediction [4], [8], [9]. Although all these efforts have produced positive results, not many studies were dedicated to examining the blooming process progression as the reliable predictor of mango yield. Thus, the current research aims

at studying the flowering process at different stages with an aim to forecasting mango yield and developing the system of systematic monitoring of phenological processes.

Related work

There has been a growing tendency for image-based crop monitoring, according to recent studies. Kumar and Patel [1] suggested the use of YOLO-based methods for detecting and categorizing flowers and buds in mango crops. Sharma et al. [5] explored deep learning techniques for classifying different stages of flowering in mangoes and recognized the significance of the phenology aspect in orchard monitoring. Patel et al. [6] introduced computer vision approaches for determining the flowering intensity in mango trees and proved the high reliability of their observations when compared to manual assessments. In a similar vein, Chopra et al. [7] proved that machine vision systems can be successfully employed for flowering evaluation in orchard conditions.

There are several other researches which presented various studies studying productivity forecasting by means of environmental and remote sensing data. Torgbor et al. [4] combined climatic factors and remote sensing information for predicting harvest yields. Ali et al. [8], for instance, used data received from UAV for evaluating flowering season and its further analysis. Faye et al. [9] also provided examples of productivity assessment based on UAV technology.

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

Study	**Flower Detection**	**Temporal Monitoring**	**Yield Estimation**
Kumar and Patel (2024) [1]	Yes	No	No
Sharma et al. (2020) [5]	Yes	Limited	No
Patel et al. (2025) [6]	Yes	No	No
Torgbor et al. (2023) [4]	Indirect	Yes	Yes
Ali et al. (2025) [8]	Indirect	Yes	Yes
Present Study	Yes	Yes	Future Scope

The review shows that flowering detection and yield forecasting have been treated separately so far. More research has to be done to find out how the process of flowering affects the yield in the future.

Key Contribution

The study contributes to the existing body of knowledge in the following ways:

1. Considers mango flowering development from the procedural perspective.
2. Collects a number of images at different stages of mango flowering.
3. Explores characteristics of images captured at different stages of mango flowering and fruit setting.
4. Makes a groundwork for the future research in yield forecasting processes based on time-dependent data.
5. Presents a successful example of orchard monitoring through images captured on the field.

Method, Experiments and Results

Dataset Collection

An image collection strategy was established based on the field in order to observe changes in the flowering stage of the mango trees. Since the image obtained varies depending on the direction in which the photo has been taken, the images were taken from the north, south, east, and west directions.

Table 2. Dataset Design

Parameter	**Value**
Trees	25
Viewing Directions	4
Observation Stages	Flowering to Early Fruit Development
Images per Stage	100
Total Images	200

The image dataset was meant to capture the transition between the flowering stage and the initial phase of fruit formation.

Image Processing

The recorded images underwent standardized preprocessing procedures, including resizing, noise elimination, canopy segmentation, color-space transformation, and standardization.

The initial stages of flowering can be characterized by dominant color features, whereas later developmental phases increasingly include texture properties. Therefore, to enable stage-based analysis, the HSV color model was used.

Temporal Monitoring Framework

The overall workflow used in this research is shown in Figure 1. The sequence of observations comprises the flowering stage and early fruit development stage, which are arranged temporally for future yield forecasting.

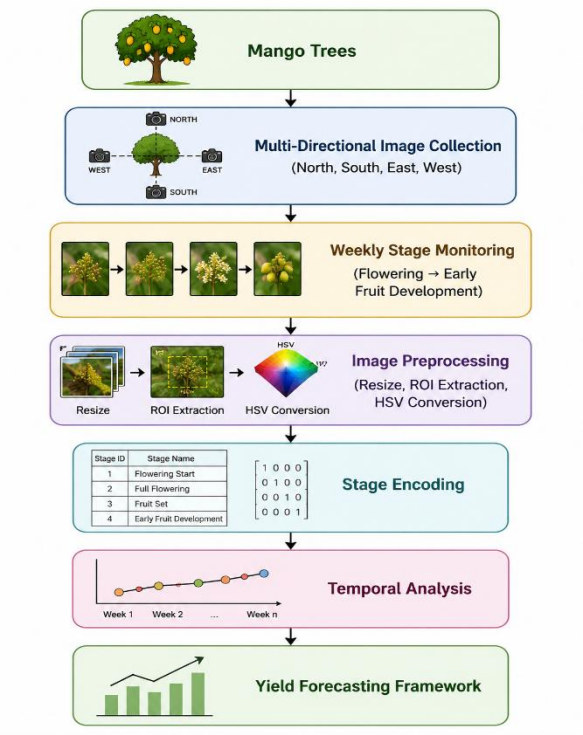

Figure 1. Workflow adopted for temporal monitoring of mango flowering progression and yield forecasting.

Results and Discussion

Visual analysis of captured images revealed marked differences between the various development stages. Flowering stages had flowers forming on dense floral regions with pronounced coloration, while fruiting stages had increasing complexity in structure and texture with respect to the process of fruit formation. Due to the findings brought out, it can be confirmed that there is significant information on flowering progress with respect to phenology in its implications with reference to the future yield predictions. Therefore, unlike in the previous researches where flower detection [1], [6], [7] only and environmental modelling [4], [8], [9] have been observed, this work gives much emphasis to flowering stages succession over time. The established dataset and monitoring framework is very useful for subsequent investigations as part of flowering yield predictions. The structured dataset and monitoring framework developed in this study provide an important foundation for future investigations into flowering-based yield prediction. Furthermore, the field-oriented image acquisition strategy offers a practical and comparatively low-cost alternative to more complex sensing systems.

Conclusions

1. The research pointed out the lack of systematic observation of the flowering process for mango yield prediction.
2. A method called temporally observing process was developed based on multi-directional image capturing at different developmental stages of flowering and fruiting processes.
3. The collected data indicated that different flowering processes occurred at different periods

4. According to the research, the use of phenological information will be helpful for future studies on yield forecasting.
5. In future research, the integration of the environmental factors into the model will be performed.

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