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MODELLING THE DYNAMIC RESPONSE OF ROOT AND STEM DIAMETER CHANGES IN DENDROBIUM AND VANDA ORCHID TO TEMPERATURE AND HUMIDITY USING NARX NEURAL NETWORKS

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ABSTRACT

The agricultural sector, crucial for food security and economic growth, is being transformed by technological innovations such as precision agriculture and smart farming. Precision agriculture enhances crop yields by effectively managing soil and water resources, while smart farming integrates these practices with Internet of Things (IoT), robotics, and artificial intelligence (AI) to further improve efficiency. In Malaysia, the floriculture industry is actively leveraging research and development to increase profitability. Key areas of focus include germplasm enhancement, variety development, and quality improvement. Efficient water management is a critical aspect of smart agriculture, particularly in ensuring optimal water use efficiency for various plants. Accurate monitoring of plant water status is essential for achieving this goal. Despite limited research on the growth response of epiphytic plants like orchids to environmental factors, this study selected two orchid types: a sympodial and monopodial. A sympodial orchid has a rhizomatous growth pattern, while a monopodial orchid has a single stem that grows from the base. To address this, a Nonlinear Autoregressive Model with Exogenous Inputs-Multilayer Perceptron (NARX-MLP) was applied to predict the water status based on changes in root and stem diameter as output (ny), utilizing temperature (nu1), relative humidity (nu2), and hidden nodes (h). The NARX-MLP model identified optimal input-output lags, and hidden nodes settings for different orchid parts, formatted as nu1:nu2:ny:h, achieving near-perfect R-squared (R2) values and low mean squared errors(MSE), demonstrating high predictive accuracy and precision. The findings indicate that for the NARX-MLP model, the optimal configurations of inputs-output lags and hidden nodes, are accurately modelling the orchid roots, monopodial stems, sympodial stems, and sympodial growth are 11:11:11:17, 15:15:15:13, 13:11:13:18, and 20:19:20:16, respectively. The R^2 values, which represent the model's accuracy, were exceptionally high for all plant parts: 0.9999 for both roots and monopodial stems, and a perfect score of 1 for both sympodial stems and sympodial growth. Similarly, the MSE, which measure the average of the squares of the errors or deviations, were very low: 2.25 x 10-5 for roots, 2.12 x 10-5 for monopodial stems, 4.48 x 10-6 for sympodial stems, and 1.55 x 10-6 µm for sympodial growth. The total correlation violation values (TCV), which calculate the total amount correlation that exceeded the 95% confidence interval during correlation tests, indicate the model's consistency. The TCV were 0.04255 for roots, 0.00826 for monopodial stems, 0.000214 for sympodial stems, and 0.20467 for sympodial growth, demonstrating the model's reliability in predicting water status for different orchid parts. This research supports smart farming by providing a reliable tool for monitoring water status and managing orchid growth efficiently in future.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Water, an essential component for all living organisms [1, 2], constitutes about 70% of the Earth's surface. Of this, 97.5% is saline water, while only 2.5% is fresh water. Moreover, just a small portion of this fresh water is accessible for use [3]. Research indicates that agriculture consumes 70% to 80% of the world's water supply [4-6], with irrigation accounting for 60% of this agricultural water use [4, 7]. Despite water's critical role in agriculture [8], the sector confronts significant hurdles due to water scarcity and the imperative of adopting sustainable water management practices [9].

Agriculture has been pivotal in the development of human societies, providing essential nourishment and catalysing economic and social progress [10, 11]. Its importance is manifold, including ensuring food security [12, 13], contributing significantly to the global economy by offering employment and income to millions [14] and enabling environmental sustainability [13, 15] through the adoption of practices and technologies that reduce environmental degradation. Additionally, agriculture is integral to cultural identity and heritage [16], fostering a sense of pride [17] within communities across various cultures. Beyond its core activities of crop cultivation, livestock rearing and resource management, the sector also generates vital raw materials for industries like alternative medicine, textile manufacturing, and landscaping [18].

Recent studies on agriculture field have significantly advanced agricultural management, increasing crop yields, optimizing resource use, and enhancing disease resistance, all underpinned by technological progress [19]. Smart farming encapsulates this progress, melding precision agriculture with modern technologies to elevate farming efficiency. Smart farming leverages data analytics and artificial intelligence to refine agricultural methods [20], employing drones and sensors for data acquisition and machine learning for analytical insights to guide decisions. As a cornerstone of agricultural innovation, precision agriculture has played a pivotal role [21], improving yields [22], seed quality [22], and enabling precise monitoring [23]. Its benefits extend