AI-Driven Insights: Forecasting Dendrobium Sampran Growth with Neural Networks in Photoselective Shading

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Abstract—**Orchid cultivation is a crucial aspect of the Philippines' agricultural landscape, with over 900 indigenous species in the archipelago. However, the industry has declined due to various factors, including the destruction of natural habitats and limited cultivation efforts. This study investigates the impact of shade netting on the growth of Dendrobium Sampran orchids, employing an Artificial Neural Network (ANN) to analyze environmental variables such as temperature, humidity, and light intensity. The research aims to optimize growth conditions and enhance production quality using different shade net set-ups. The findings reveal that specific set-ups, particularly those using green shade nets at 50% and 75% shading, significantly improve growth metrics, including the number of buds, flowers, leaves, and plant height. The ANN model demonstrated predictive solid accuracy, with the lowest Mean Squared Error (MSE) values observed in these set-ups, indicating their effectiveness in fostering orchid development. Additionally, the study aligns with sustainable development goals by promoting responsible cultivation practices that minimize environmental impact and support biodiversity conservation. This research contributes to revitalizing the Philippine orchid industry and preserving its rich floral diversity by optimizing the growth environment through shade netting.**

Keywords—**Artificial Neural Network (ANN), dendrobium, net, Orchids, shading**

I. Introduction

The most prominent monocotyledonous family in the Philippines is Orchidaceae. Up to this point, the archipelago has been home to around 137 genera and 998 species of orchids. This constitutes approximately 10% of the Philippines' floral diversity [1]. In the Philippines, there are numerous wild orchid species. However, because of the destruction of their natural environments and inflexible collection, many wild orchid species are now in danger of extinction. Maintaining and growing these species in botanical gardens should be a priority. There was an increase in plant demand, such as orchids, during the pandemic. However, as the pandemic ends, enthusiasts for orchids and ornamental plants become more mobile. Very few were cultivating and marketing Philippine orchids. The continuous decline in the plant's production results from decreasing interest. Continuous improvement is required in both orchid plantlet quality and production.

Orchids are highly adapted to their surroundings. They have effectively colonized every habitat where the light shines. Blooms of orchids are frequently colorful and fragrant. Due to rising demand from new businesses, growing tourism investments, and increasing disposable income, the market for flowers and ornamental plants is growing in the Philippines. Dendrobium Sampran is climatically and environmentally adaptable. The topography changes from warm, muggy lowlands to cool, higher elevations [2].

Internal microclimate factors, including air temperature, humidity, and the type and amount of light, impact orchid growth. Utilizing shade netting provides a range of climatic and environmental variables to track changes in orchids' physical development. The data observation of the impact of differences in topography on the growth of orchids will be made easier with technology such as Artificial Neural Networks (ANN). It uses various mathematical processing levels to make sense of the data it is fed. ANN models can precisely use unlimited input and output parameters for optimum system performance. These are self-adaptive, data-driven systems that can model or uncover complex non-linear processes in an adaptable way, supplying information that may be incorporated into a different neural network. Converting input data into a predicted output may roughly approximate nearly every part of the input-output map and enhance the performance of statistical classifiers under challenging problems that cannot be solved linearly. They frequently employ approximation functions and back-propagation techniques to learn in the buried layer. Production development will benefit horticulture and agriculture.

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The primary objective of this study is to investigate the impact of shade netting on the growth of Dendrobium Sampran, a type of orchid, by analyzing data observations through an Artificial Neural Network (ANN). The researchers aim to modify the orchid's growth environment using shade netting to regulate the quality and quantity of light and temperature and humidity levels. Orchids have specific temperature tolerance ranges, and within that range, there exists an optimal temperature range where they exhibit the fastest growth due to their efficient nutrient and water absorption, enabling them to utilize available light effectively and maintain leaf hydration [3]. As tropical orchids generally lack robust root systems, creating a warm and humid environment is crucial for their successful growth [4]. Humidity will be quantified by measuring moisture intake and loss within the growth structure [5]. The ANN will help analyze the collected data, allowing the researchers to assess the effects of shade netting on Dendrobium Sampran's growth rate and overall development.

Despite 1100 orchid species, including 900 indigenous species that can only be found in the Philippines, the country's orchid industry is currently in decline [6]. It will be possible to cultivate and boost the output of orchids by keeping an eye on the adjustments that will be made to the garden environment where they will develop. This study aligns with Sustainable Development Goal (SDG) 12: Responsible Consumption and Production by optimizing orchid cultivation practices and increasing productivity, as it can contribute to developing sustainable practices in orchid cultivation, such as optimizing resource use and minimizing environmental impact. Additionally, this study is consistent with SDG 13 and SDG 15, Climate Action and Life on Land. Since extreme weather events like high heat and heavy rain are becoming more frequent owing to climate change, shade nets can shield plants from these elements. The study offers recommendations based on empirical data for the efficient use of these nets, thereby reducing the harmful effects of harsh weather on crop yields. By doing so, there is less need to gather wild orchid populations, aiding in preserving biodiversity and natural ecosystems. Resilient ecosystems are enhanced by the presence of healthy plants, which also aid in soil stability and nutrient cycling. This is especially crucial in the fight against land degradation and desertification in susceptible places.

Furthermore, the study can potentially decrease the utilization of chemical pesticides and fertilizers by enhancing plant health and growth conditions. Preventing chemical runoff, which can destroy terrestrial ecosystems and jeopardize biodiversity, and preserving soil health are crucial. To preserve soil moisture and avoid erosion, employing shade netting and meticulously controlling environmental factors can be beneficial. Particularly in regions where soil deterioration is a problem, this is crucial. The study helps maintain fertile, healthy land by endorsing soil preservation methods.

II. Methodology

A. Research Design

The study is conducted in a garden at an elementary school on the corner of Abad Santos and Recto Avenue. By limiting the amount of light received and influencing other environmental components like air and soil temperature, humidity, air velocity, and ventilation rate, screens and nets employed as shading devices can regulate how quickly a plant develops. Thus, using an artificial neural network, the effects of black and green shade nets on Dendrobium Sampran and the shade percentage they provide were determined. Subjects will be assigned to various treatments in this study using a Completely Randomized Design. As shown in Fig. 1, the study will have ten set-ups, including two control groups and six sample groups. The control group is the Dendrobium Sampran without garden shade nets above the set-up. There are three replicates of orchids for each set-up, in which the study lasted for three months. The data on the following variables that may affect the set-up are collected every 4 hours: temperature, humidity, and light intensity. The components of orchids that are measured every day are the number of flowers and buds, the height of the plant, and the number of leaves. Artificial Neural Network (ANN) is used to analyze the correlation between the growth of orchids and photoselective shade nets after three months of collecting data.

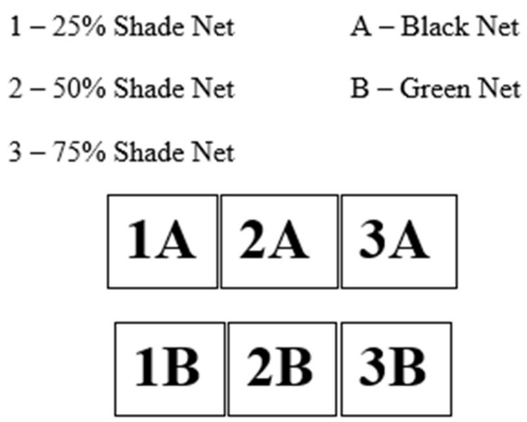

Fig. 1. Research design of testing of Dendrobium Sampran.

1) *Sample population*

All of the seedlings of Dendrobium Sampran are bought from one store. The coconut husk that acted as soil used in the study was also purchased from the same store. The garden shade net also came from one store on Metro Manila premises. Twenty-one seedlings of Dendrobium Samprann and three black and green nets will be bought.

2) *Sample preparation*

There are seven (7) set-ups with different net colors and shade percentages. The first three set-ups use a black net, but with varying shade percentages, there are 25%, 50%, and 75% shade net percent. The other three set-ups use green nets with the exact shade percentages. The last set-up is the control variable, with the orchid without the shade nets. Each set-up consisted of three replicates of the orchid to ensure a reliable and accurate result. The plants are planted in a black orchid pot with coconut husk for orchids as its field soil and irrigated using overhead misting.

B. Statistical Analysis of Data

The study aimed to determine the most suitable environment for orchids by collecting temperature, humidity, and light intensity data over three months. The collected data served as input variables, while the number of buds, flowers, leaves, and plant height were the output variables. The absolute value of the obtained differences in the growth rate of the orchids was used as data. The effectiveness of each environment set-up was compared based on the resulting r-squared value obtained from an Artificial Neural Network (ANN) model developed using MATLAB's Pattern Recognition Tool. The ANN model was tested with varying numbers of nodes in the hidden layer, using daily average temperature, average daily humidity, and light intensity as inputs and the growth rate of the orchids over 90 days (about three months) as the output [7]. The optimal number of hidden layers and nodes was determined through a trial-and-error approach. The prediction performance of different methods was evaluated using the mean square error criterion.

The data processing involved collecting 483 data points on the impact of photoselective shade netting on Dendrobium Sampran's growth. The data included input variables such as temperature and humidity and output variables like the number of buds, flowers, leaves, and plant height. The absolute value of the differences in the growth rate of the orchids was used as data to train the neural network. The data was divided into 70% training, 15% validation, and 15% test data.

For model validation and structure selection, the Levenberg-Marquardt algorithm was chosen due to its ability to handle non-linear problems and its robustness in noisy data. The algorithm is particularly effective in optimizing the parameters of the neural network by iteratively adjusting the weights and biases to minimize the error between the predicted and actual output values [8]. The model structure consisted of 10 layers, with the optimal number of nodes in each layer determined through a trial-and-error approach. The model performance was evaluated using the mean square error criterion. The Levenberg-Marquardt algorithm's ability to balance the trade-off between the two opposing forces of gradient descent and Newton's method made it a popular choice for neural network training [9, 10]. The resulting r-squared value obtained from the Artificial Neural Network (ANN) model developed using MATLAB's Pattern Recognition Tool was used to compare the effectiveness of each environment set-up.

III. Results and Discussion

A. Growth Rate under Different Shade Nets

The growth rate of Dendrobium Sampran orchids was analyzed using a graph created in Excel that plotted the number of buds, flowers, leaves, and plant height against the date over the 3-month study period. This raw data graph visually represents how the different growth metrics changed over time under the various shade netting treatments. The graph revealed clear trends in the growth trajectories of the orchids, with some set-ups exhibiting faster growth rates and higher yields of buds, flowers, and leaves than others.

The graph of the number of buds over time showcases the varying responses of Dendrobium Sampran orchids to the different shade netting configurations. Fig. 2 shows set-up 2B demonstrates a substantial increase in buds, followed closely by set-up 3B. However, both set-ups exhibit bud decline during the last two weeks of the observation period. This trend indicates a potential limitation in sustaining bud development as the experiment progresses, warranting further investigation into the factors influencing this decline.

The number of flowers produced by the orchids is a crucial indicator of their overall health and reproductive success. Fig. 3 reveals that set-ups 2B and 3B consistently outperform the other configurations, with a steady increase in flower counts over the three months. Similar to the bud data, there is also a decline or stabilization in the number of flowers during the last two weeks. This pattern is consistent with the findings for the number of buds. The control group, while showing a significant increase in flower production during the middle of the experiment, ultimately faces a decline due to insect infestations that hinder its ability to maintain flower counts.

Leaf growth is essential for photosynthesis and overall plant vigor. Fig. 4 indicates that set-up 2B maintains the highest leaf count throughout the experiment, exhibiting a constant value. Set-up 3B shows a steady average increase in leaf number. In contrast, the control group demonstrates a more gradual increase, with some periods of decline. This highlights the benefits of shade netting in enhancing leaf growth, suggesting that the controlled environments provided by the nets contribute positively to leaf production.

Plant height is a reliable indicator of overall growth. Fig. 5 reveals that set-ups 2B and 3B consistently outperform the other configurations, exhibiting a pronounced increase over time. The control group shows a rapid initial height increase but experiences a slowdown as the experiment progresses. This emphasizes the importance of optimizing environmental conditions for enhanced vertical growth, as the control group's inability to sustain growth rates may be linked to the lack of shade netting.

The graphs depicting the raw data clearly represent how Dendrobium Sampran orchids respond to various shade netting configurations. The outstanding performance of set-ups 2B and 3B across all growth parameters - number of buds, flowers, leaves, and plant height - suggests that these environments are ideal for orchid cultivation. In contrast, the control group, which lacked shade netting, underscores the advantages of shade nets in enhancing overall plant growth and development.

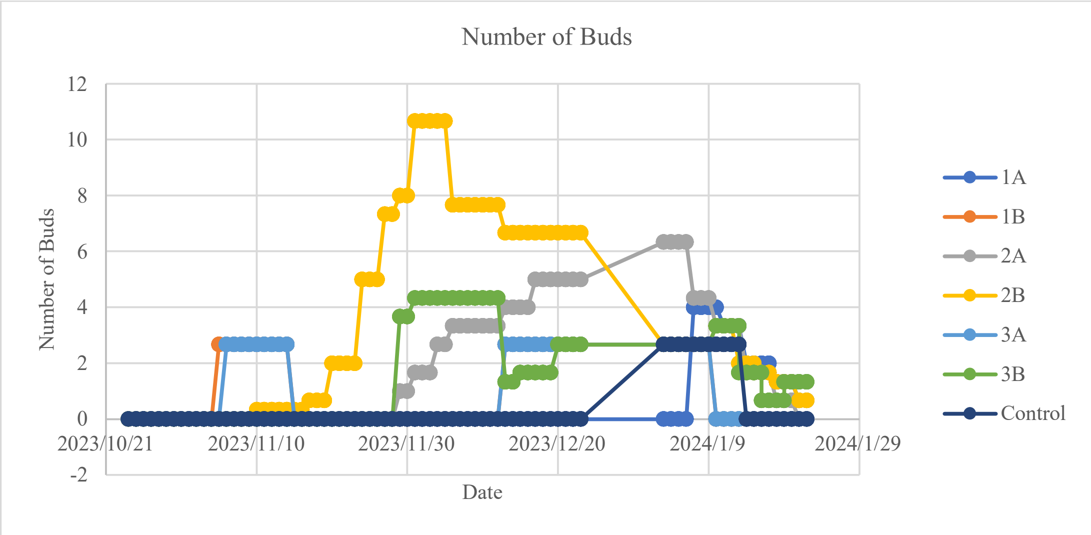

Fig. 2. Number of buds for 3 months.

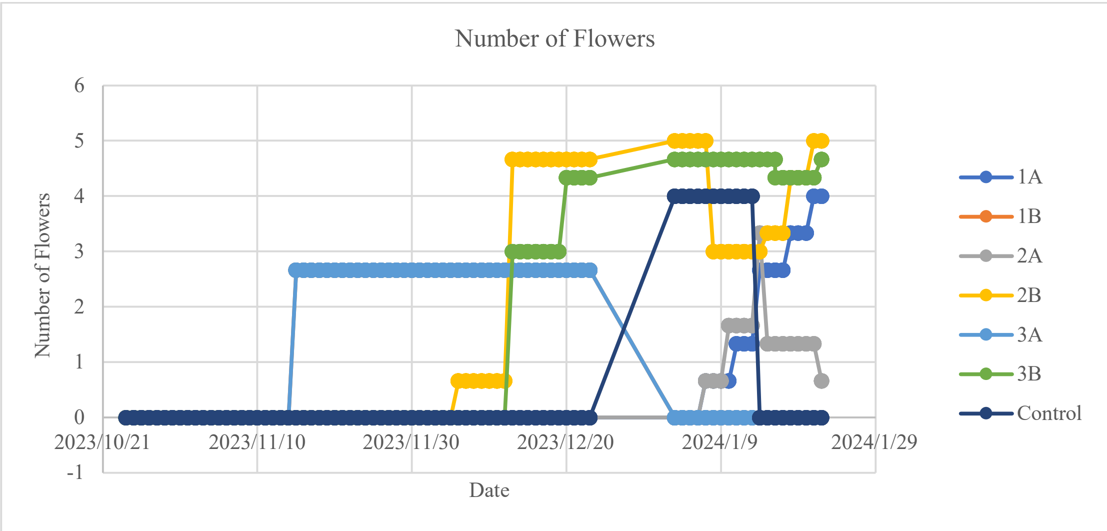

Fig. 3. Number of flowers for 3 months.

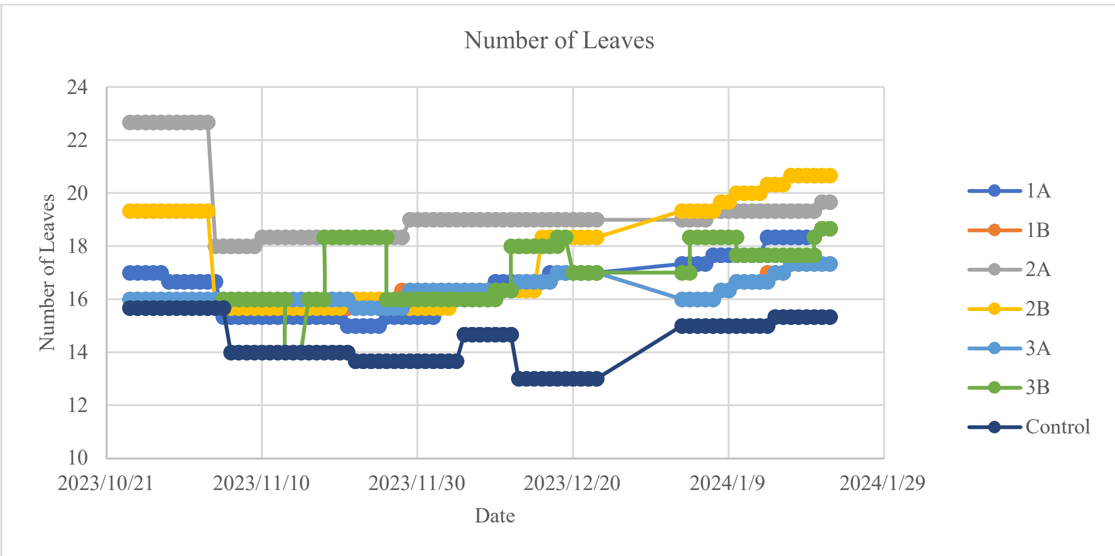

Fig. 4. Number of leaves for 3 months.

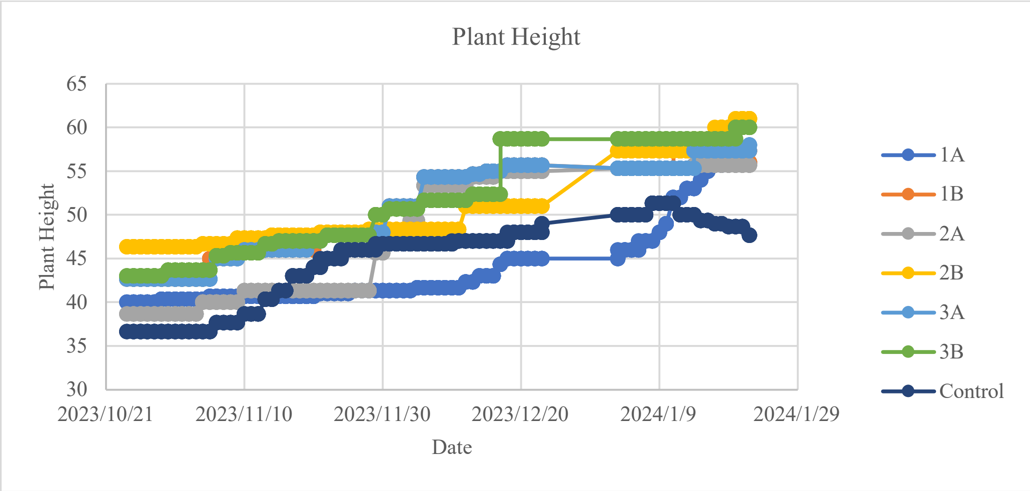

Fig. 5. Plant height for 3 months.

B. Artificial Neural Network (ANN) Results

The application of Artificial Neural Networks (ANN) in this study is a powerful tool for analyzing the impact of photoselective shade netting on the growth of Dendrobium Sampran orchids. By leveraging a robust dataset that includes critical environmental variables such as temperature and humidity, the ANN model is designed to uncover complex relationships between these inputs and the resulting growth metrics, including the number of buds, flowers, leaves, and plant height. The model's architecture, trained using the Levenberg-Marquardt algorithm, effectively handles non-linear interactions within the data. This section will delve into the performance metrics of the ANN, including the Mean Squared Error (MSE), regression analysis, and error histogram, to evaluate the model's predictive accuracy and its implications for optimizing orchid cultivation practices.

1) Mean Squared Error (MSE) result

Using the Levenberg-Marquadt algorithm in MATLAB to train the Artificial Neural Network (ANN) model, the relationship between the orchid's growth and its environment was estimated and evaluated to determine which set-up suits the flower the most. One of the primary performance metrics for assessing the model's accuracy is the Mean Square Error (MSE). The table below shows the summary of MSE results for the training, validation, and test datasets for each set-up.

The MSE values for the training, validation, and test sets across each set-up must be assessed to establish, based on the performance of the ANN model, which growth environment is optimal for orchids. When the MSE value is lower, the model performs better; the ANN predictions are more accurate in predicting the actual observed values.

TABLE I. MEAN SQUARED ERROR (MSE) RESULT

Data Sets	Control	1A	2A	3A	1B	2B	3B
Training	18.9564	4.6397	10.5646	5.3470	4.9692	1.9122	2.1918
Validation	24.8932	3.9509	9.0343	5.4434	5.0988	2.4530	1.8759
Test	17.4105	6.3258	8.2963	4.8431	4.8506	1.6451	2.2055

By analyzing the MSE result in Table I, the set-ups with the most promising values are 2B and 3B, as they have the lowest MSE values for all three categories compared to other set-ups. The lowest values were obtained with MSE values of 1.9122 and 1.6451 in the testing and training stages of set-up 2B, respectively. It indicates that the system is well-tuned and less prone to overfitting. Strong performance during testing and training is demonstrated. The results of 2B suggest that the model's performance is consistent over diverse datasets and performs well during the training phase. It is essential for practical and real-world applications since the model will behave similarly on fresh data.

Across all datasets, 3B performs more consistently, which suggests improved generalization. The model's performance on validation is good, indicating a very effective current model despite the somewhat higher test phase's MSE.

The set-ups with a green net and 50% netting density perform well regarding MSE findings. However, based on this model's evaluation, 2B performs somewhat better in test MSE, indicating that it may be the best option for boosting orchid development. However, 3B remains a strong candidate, especially given its performance on the validation set. This result demonstrates that set-up 3B is quite successful in the current context, delivering the most outstanding fit and forecast accuracy for known conditions. It guarantees that appropriate growth conditions are satisfied in the current context, making it excellent for preserving the current environment. 2B demonstrates more generalization and adaptation to novel or varied environments, even while still effective in the current setting.

2) Regression plot

Another essential factor in evaluating each model is the regression result from training and testing the model. Along with a regression diagram showing how well the ANN model's projected values correspond with the actual values, the R-values and fit line equations are used to evaluate the regression result. The table below summarizes the R-values derived from simulating every set-up.

TABLE II. REGRESSION RESULT

Data Sets	Control	1A	2A	3A	1B	2B	3B
Training	0.9746	0.9927	0.9858	0.9930	0.9934	0.9977	0.9972
Validation	0.9709	0.9939	0.9887	0.9930	0.9933	0.9970	0.9977
Test	0.9761	0.9909	0.9894	0.9936	0.9936	0.9981	0.9972
All	0.9739	0.9925	0.9867	0.9931	0.9934	0.9976	0.9973

Table II shows that the R-values for all set-ups are very high across training, validation, and test data, indicating that the models are very good at fitting the data and making highly accurate predictions. Although all set-ups have strong R-values, it is clear that set-ups 2B and 3B have greater R-values and are closer to 1, proving and strengthening their MSE results.

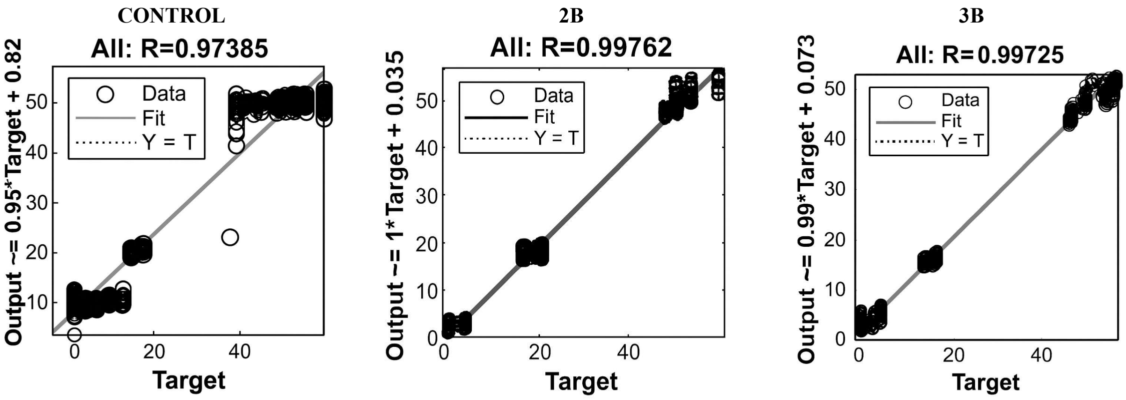

Fig. 6. Regression plot of control, 2B, and 3B.

Regression plots reinforce the connection between environmental factors and orchid development by graphically representing how well the neural networks predicted outputs match the target values. Fig. 6 shows the combined training, validation, and test regression plots of the control, 2B, and 3B set-ups. The target variable, or input, is represented by the x-axis as the environmental conditions, and the output variable, or development of the orchid, is defined by the y-axis.

TABLE III. FIT LINE EQUATIONS

Set-up	All
Control	Output = 0.95×Target + 0.82
1A	Output = 0.98×Target + 0.24
2A	Output = 0.97×Target + 0.47
3A	Output = 0.99×Target + 0.38
1B	Output = 0.99×Target + 0.19
2B	Output = 1×Target + 0.035
3B	Output = 0.99×Target + 0.073

Ideally, the data points would fall along a 45-degree angle, indicating a perfect fit in which the model's predictions match the actual values. Fig. 6 demonstrates that the data points in 2B and 3B cluster around the fit line, indicating high predictive performance. Meanwhile, the data points in the control plot are more evenly distributed around the regression line. There are several outliers, with some values falling significantly below and above the line, indicating that the model has difficulty predicting the plant growth parameters for the control set-up. The model's predictions are inaccurate for several of the control data points.

The fit line equation is another factor to consider when determining the model's correctness since it mathematically represents the relationship between the input and output variables. In a perfect regression scenario, the ideal fit line is output = target or output = 1× target + 0, and any divergence from this line shows prediction errors. Table III shows that other set-ups than 2B deviate significantly from the ideal fit line, indicating less accurate predictions and the existence of systematic error and bias since the slope is less than one and their intercepts are more than 0. With the fit line equation result, it can be said that 2B is the best set-up for orchid development. The conclusion that 3B is best for the current environment and 2B offers superior generalization for a broader range of situations is supported by the R-values, regression plot, and fit line equations of each set-up described in this subsection, which are following the MSE analysis covered in the previous section.

3) Error analysis

The error histograms for the two set-up configurations with the highest R-squared values, 2B and 3B, are analyzed to assess the performance and accuracy of the neural network model in predicting the impact of photoselective shade netting on Dendrobium Sampran's growth. Each histogram displays the distribution of errors between the target values and the predicted values, with the total error range divided into 20 bins.

The error histogram analysis for set-up 2B on Fig. 6 reveals a significant concentration of errors centered around −0.07757, indicating a tendency for the model predictions to underestimate the actual growth metrics of Dendrobium Sampran orchids slightly. The training dataset exhibits a frequency below 600, while the validation and test datasets show frequencies ranging from 600 to 900. This suggests that the model performed relatively well across different datasets, although the training dataset had a marginally lower frequency of errors. Notably, the zero-error point aligns with the bin centered at −0.07757, further emphasizing the model's slight bias towards underestimation in this configuration. The distribution of errors indicates a broader range of prediction accuracy, which could have implications for the model's reliability in practical applications.

In contrast, set-up 3B presents a narrower error distribution, with the error histogram centered around −0.151. The training dataset in this configuration shows a significantly lower frequency of errors, below 250, while the validation and test datasets have frequencies between 250 and 350. This narrower distribution suggests that the model in set-up 3B is more consistent in its predictions, albeit with a more pronounced underestimation of growth metrics compared to set-up 2B. The zero-error point also falls within the bin centered at −0.151, indicating that the model's predictions are consistently skewed towards this negative error. This characteristic may limit the model's applicability in scenarios where precise growth predictions are essential.

When comparing the two set-ups, it is evident that set-up 2B offers a more balanced error distribution, allowing for a broader range of prediction frequencies. In contrast, set-up 3B demonstrates a more focused but consistently negative error trend. The broader frequency range in set-up 2B may provide a more versatile model for various growth conditions, whereas the narrower distribution in set-up 3B could indicate a more specialized application with potentially less variability in predictions. This could be attributed to factors such as the specific configuration of the neural network architecture, the quality and quantity of the training data, or the effectiveness of the hyperparameters used during the training process [11]. This information is essential for optimizing the growing conditions and maximizing the yield of Dendrobium Sampran orchids.

IV. Conclusion

The study on the growth of Dendrobium Sampran orchids under different shade netting conditions reveals significant findings regarding the optimal set-ups for enhancing growth rates. The analysis indicates that set-ups 2B and 3B, which utilized green shade nets with 50% and 75% shading, consistently outperformed other configurations across multiple growth metrics, including the number of buds, flowers, leaves, and overall plant height. Specifically, set-up 2B exhibited the lowest Mean Squared Error (MSE) values during the training and testing phases, suggesting a well-tuned model that accurately predicts growth outcomes under controlled conditions. This set-up also demonstrated a high R-value, indicating a strong correlation between the predicted and actual growth metrics. It further supports its efficacy as an optimal growth environment for orchids.

In contrast, the control group, which lacked shade netting, showed initial growth but struggled to maintain its rates, mainly due to insect infestations that affected flower production. The ANN analysis reinforced these findings, revealing that while all set-ups had high R-values, set-ups 2B and 3B were superior in predictive accuracy and generalization capabilities. Thus, the study concludes that employing shade nets, particularly the green net at 50% shading (set-up 2B), is the best approach for cultivating Dendrobium Sampran orchids, as it not only enhances growth rates but also provides a resilient environment that can adapt to varying conditions, ultimately supporting sustainable orchid cultivation practices.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

NDS provided expert oversight throughout the project, ensuring its smooth execution while maintaining the highest academic standards. Her ongoing support was crucial in shaping the direction of the study, and her thorough review of the manuscript's content ensured that the research met stringent academic criteria. PPMAA and ELTD played vital roles in the execution and dissemination of the research. They were responsible for conducting the study, overseeing the extensive data collection processes, and performing comprehensive data analysis. Additionally, they collaborated on the manuscript, drafting and refining it for publication. All authors had approved the final version.

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