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Artificial Neural Networks to Predict Melon (*Cucumis melo L.*) Production in Tropical Greenhouse, Indonesia

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Abstract

Quality of melon indicated by size (fruit weight), appearance, and sweetness. Melons with a weight of 800 to 1,200 grams per fruit are favored by the public and have their own market share. Mainly, the melon was cultivated in open fields during the dry season with several limitations of cultivation. To cope with those problems, melon was cultivated inside the greenhouse. However, there are several parameters influenced by melon quality inside the tropical greenhouse with hydroponic system. There were a few studies on the prediction model development of melon inside the greenhouse in a tropical area, Indonesia. The aim of this study was to develop an artificial neural networks (ANNs) model to predict the melon production inside the greenhouse (fruit weight) using several parameters such as the number of days to fruit formation, number of days to maturity, plant length, fruit width, fruit length, fruit cavity diameter, flesh diameter, branch number, fruit branch number, and leaf number. The result of this study was the ANN model with configurations of 10 input layers, 6 hidden layers, and 1 output layer with R^2 *was 0.9312. This study concluded that there is a correlation between the input parameters with the weight of the melon.*

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1. Introduction

Melon is one of the most popular fruits in Indonesia, because melon is a fruit crop that has a high value (Christy 2020). Melon production in Indonesia is quite high, reaching 118,696 tonnes in 2022 (Badan Pusat Statistik 2022), therefore melon fruit is very potential as an export commodity (Hutabarat *et al*. 2019). Cultivation of melons in open fields supplies most of the needs for melons in Indonesia; however, environmental factors such as high intensity of rainfall, heat, strong winds, as

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well as disease issues, have affected the quality of the melons. To overcome these problems, the use of greenhouses is an alternative solution in controlling microclimatic conditions, because greenhouses have the advantage that plants can grow and produce throughout the year, the risk of pest attacks and the threat of plant diseases is lower (Suhardiyanto 2023) (Toiba *et al.* 2023).

The quality of the melon fruit includes size, appearance, colour, and taste, as well as the level of sweetness (Setiawati dan Bafdal 2020, Badan Standardisasi Nasional 2013). Fruit weight is often a consideration for consumers in consuming melons. Several methods that can be used to identify fruit weight are using plant morphological and phenological characteristics. Melon production is indicated by the weight of melon fruit produced per plant. Melon fruit weight is often a consideration for consumers in consuming melon fruit, where melon fruit weight can reach 2000 gram/plant, but certain consumers prefer melon fruit weight with a size of 800-1200 grams. One that can be used in identifying fruit weight is using morphological characteristics and plant phenology. These characteristics can be observed in the vegetative organs of plants, such as leaves, stems, and branches, as well as in generative organs, such as flowers and fruit. The tendency to use organs of vegetative growth of plants because it is considered easier and faster to obtain data, as well as being available as a source of observations all the time, while the generative organs of plants can only be observed at certain times (Nasution Nur Hanifah 2016).

Identification of fruit quality can be made with a regression approach and machine learning. The use of linear regression to identify fruit quality has been carried out by (Sulistyo *et al.* 2020). A neural network-based approach has been carried out (Whidhiasih 2015), who developed an artificial intelligence system model for the non-destructive classification of starfruits using the fuzzy neural network. Fruit productivity analysis using digital imagery and segmented using a modified cylindrical method to produce volume and used in the linear regression method to produce fruit weight worked well with an accuracy performance of 86.64% and an average execution time of 3.45 seconds (Masruri *et al.* 2019).(Sulistyo *et al.* 2020) (Ayu dan Utaminingrum 2021) analyzed the sweetness level of melons using digital images based on the texture of nets on melon rinds, and backpropagation neural network to perform classification. Estimation predictions of the qualitative characteristics of cantaloupe melon have also been developed by comparing *artificial neural networks* (ANN) with regression models (Varnamkhasti *et al.* 2018). The use of ANN to predict the final fruit of melon has been carried out in open field melon cultivation using inputs on agronomic and phenological factors to produce output in the form of fruit weight with an R^2 performance 87% (Naroui Rad *et al.* 2015).

Some of the studies above illustrate that the regression approach and *machine learning* or their combination for modelling fruit quality in general, especially melons, still need to be developed for indoor farming (greenhouses) cultivation systems. Therefore the aim of this research is to develop an

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artificial neural network models to predict melon production (fruit weight) in a greenhouse using several parameters such as the number of days to fruit formation, number of days to maturity, plant length, fruit width, fruit length, fruit cavity diameter, flesh diameter, branch number, fruit branch number, and leaf number to predict fruit production (fruit weight) of melon per plant.

2. Research Methods

2.1 Smart Greenhouse Systems

The research was conducted at the Siswadhi Soeparjo Field Laboratory, Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Technology, IPB University, Leuwikopo, Dramaga Bogor, using an 8 x 24 m smart greenhouse, as shown in Figure 1. The research was conducted in October - December 2021 involving 400 melon plants distributed in 5 rows (plant racks) measuring 0.5 m x 8 m plants with 80 plants in each row. The irrigation used as drip irrigation with a watering time of 07.00 for giving nutrition and 10.00, 13.00, and 16.00 for giving water was given through an automatically controlled drip irrigation system. The planting medium used was a mixture of cocopeat and husk charcoal with a ratio of 3:1 which was put in a 35cm x 35cm polybag.

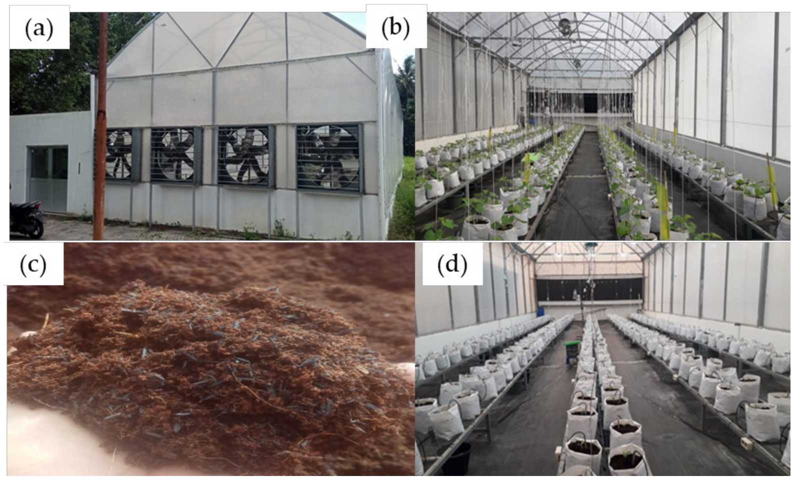

Figure 1. Research locations: (a) Greenhouse size 8 m x 24 m ^{2}; (b) melon plants of 400 plants with drip irrigation; (c) a mixture of cocopeat and husk charcoal; (d) 35 cm x 35 cm polybags that have been arranged on plant racks.

Figure 2 shows the cultivation of melon plants in a greenhouse using melon seeds of the Golden Luna variety (F1). The Golden Luna melon is oval, with golden yellow skin. The age of this plant ranges from 60-80 Days After Planting (DAP), with seeding ranging from 10-14 days. Melon fruit that is ready to be harvested has the characteristic that the leaves on the branches are dry (Figure 2). After

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harvesting, the fruit was observed for the morphological and phenological characteristics of the plant. The morphological characters of harvested plants were observed for plant length, fruit width, fruit length, fruit cavity diameter, flesh diameter, branch diameter, fruit branch number, and leaf number. The observed phenological characteristics were the number of days to fruit formation and days to maturity.

Figure 2. (a) Melon cultivation in a greenhouse; (b) Ready-to-harvest melons

2.2 Stage of Development Model

Research the development of a predictive model for melon plant weight was carried out through 4 stages, as shown in Figure 3, namely the preparation of data needed in building the model, developing a model based on an ANN, training and testing involving parameters ANN, and model validation.

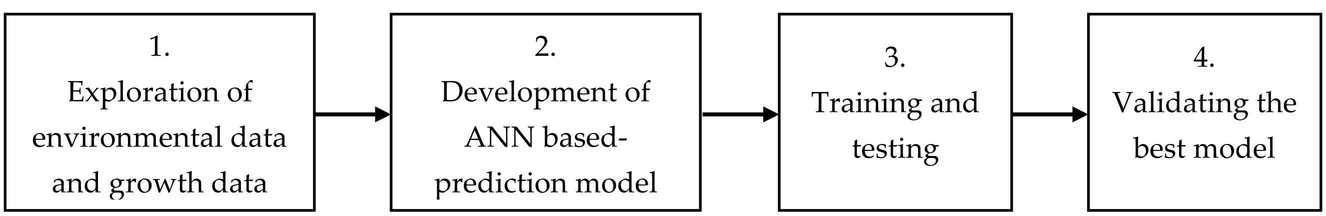

Figure 3. Research Stage

2.3 Data exploration

This stage includes data recording activities periodically throughout the melon cultivation season. The data recorded includes harvesting data and growth data needed in the development of predictive models. Harvesting data consist of several harvested fruit properties namely fruit width, fruit length, flesh diameter, fruit cavity diameter, fruit weigth, and which branches did the fruit grew on (branch number). Meanwhile growth data consist of several generative and vegetative traits of the melon crops such how many days the crop took to form the fruit and to reach maturity, the crops' length, diameter of the branches that produce the mature fruit, and number of leaves the crops had up until it harvesting time. These data are then grouped into data sets. Data collection of growth and harvesting data was carried out at the harvesting process. While recording for environmental data was carried out for two months, using weather stations placed inside and outside the greenhouse from 08.00 – 17.00. Environmental data was recorded as supportive data for this experiment.

2.4 Model Development

The learning model developed in this study uses ANN with the backpropagation algorithm, which is carried out through 3 stages, namely: 1) processing dataset, 2) model building, and 3) evaluation of prediction results. ANN is a computational method that mimics a biological neural network with a simple concept. ANN is used to develop a model of air temperature in the greenhouse, with the backpropagation algorithm as the learning method. The ANN structure consists of an input layer, a hidden layer, and an output layer, each of which is associated with a certain weight. Backpropagation uses error as a reference for changing the weighting, which consists of initializing the weighting, calculating the activation value, fixing the weighting value, and repeating.

The development of the ANN model uses the programming language python 3.7, with *the scikit-learn* library, *pandas* and *numpy library* as support (Pedegrosa *et al.* 2011). The ANN model was built in 2 scenarios, namely scenarios with seven *input* parameters, and scenarios of 10 input parameters. *The output layer* consists of the weight of the melon fruit. The best parameter values are determined based on the function coefficient of determination (R^2), *Root Mean Square Error* (RMSE), and *Mean Absolute Percentage Error* (MAPE). The predicted results of the ANN model with the *backpropagation algorithm* are then evaluated to compare the predicted data with measurement data so that the performance of the model is known.

3. Results and Discussion

3.1 Data exploration

Cultivation of melon plants was carried out in a greenhouse of 400 plants and the harvest age varied between 64-83 DAP. Statistical data obtained from observations were compiled as datasets for model development with a total of 305 datasets. The whole data set would be divided into training and validating data sets. Around 90.5% data sets (275 of them) picked randomly as training data sets, while the remaining 30 data sets are categorized as validation data sets.

The average plant length until the harvest was 243.41 cm, with an average number of leaves of 29. The results of the descriptive analysis of 11 cultivation parameters are shown in Table 1.

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Table 1. Description of statistics on ten agronomic traits of the melon population

No	Variables	Means	Min	Max	Standard error
1	Number of days to fruit formation	40.13	32	49	3.06
2	Number of days to maturity,	78.94	64	83	3.47
3	Plant length	243.41	129.3	303.5	17.74
4	Fruit width	11.81	10.2	13.1	0.5 6
5	Fruit length	12.58	9.04	14.42	0.66
6	Fruit cavity diameter	5.37	3.60	6.99	0.5 5
7	Flesh diameter	3.22	2.5	4.1	0.28
8	Branch number	20.16	8	32	3.07
9	Branch diameter	6.28	5.08	7.58	0.44
1 0	Leaf number	28.52	20	37	3.07
11	Weight	857.80	524.00	1153.00	115.25

The air temperature ranged from 26-29 °C, meaning that it is still in the range of melon cultivation conditions, where melon plants require cool and dry temperatures for growth. Meanwhile, air humidity still ranged from 78%-90%.

Changes in air temperature are also affected by the intensity of solar radiation. The higher the solar radiation, the higher the air temperature, as given in Figure 4.

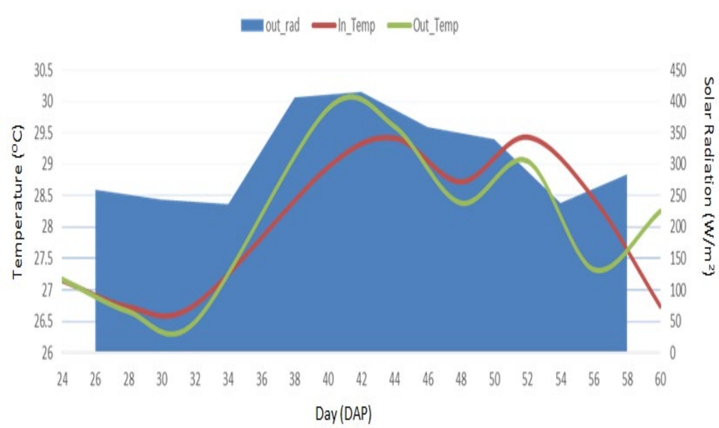

Figure 4 Air temperature conditions inside the greenhouse and outside radiation, and air humidity outside the greenhouse during melon cultivation.

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3.2 ANN-based Model Development

Ten parameters related to melon plants and fruits were used to build a melon weight prediction model with 305 datasets. The performance of the prediction model was evaluated in 2 scenarios with the strategy of changing the input parameters. Each scenario used 10,000 iterations with a learning rate of 0.6 and a momentum rate of 0.6. Both training epoch diagrams are given in Figure 5. While the model parameter schemes for both scenarios are given in Table 2. We can identify from both training epoch diagrams that the initial RMSE plays an important role for the overall training. As we can see, both training courses go through a similar process, but Scenario B has better results in the end because it has a better initial RMSE at the beginning. Moreover, this comparison emphasizes choosing the right training variables and parameters to get better training results, rather than extending the training itself. Therefore, an iteration epoch of 10000 was also decided to condense the training process. As we can see, even in the logarithmic scale displayed in Figure 5, the decrease in RMSE is not very significant after 1000 iterations. That means limiting the training to 10000 iterations is acceptable.

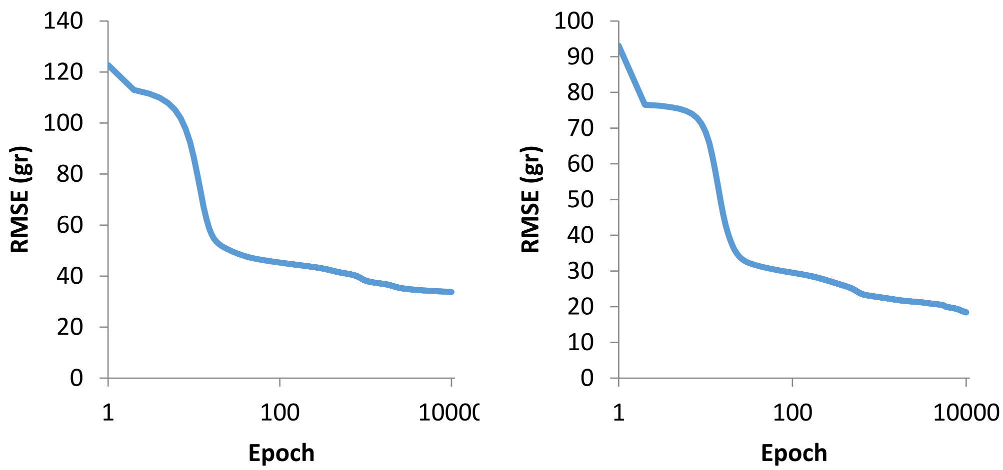

Figure 5 Root Mean Square Error (RMSE) changes through epoch on (a) Scenario A, (b) Scenario B

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Table 2. Scheme for setting the parameters of the melon fruit weight prediction model.

Description	Scenario A	Scenario B
Variables used	Fruit age, harvest age, plant height, width diameter, length diameter, fruit hollow Diameter, flesh thickness	Fruit age, harvest age, plant height, width diameter, length diameter, fruit hollow Diameter, flesh thickness, branch number, branch diameter, leaf number
Network Structure	7-4-1	10-6-1
Iterations	10,000	10,000
Learning Rate	0.6	0.6
Moment Rate	0.6	0.6
R^2	0.8456	0.9381
MAPE (%)	3.379669	1.574719
RMSE	33.79176	18.41517

Note: coefficient of determination (R^2), *Root Mean Square Error* (RMSE), and *Mean Absolute Percentage Error* (MAPE)

Modeling with scenario A using seven input parameters as done (Naroui Rad *et al.* 2015) to predict the weight of melon fruit in open fields with the ANN method, namely number of days to fruit formation, number of days to maturity, plant length, fruit width, fruit length, fruit cavity diameter, flesh diameter, found a 7-4-1 structure as the best model with a coefficient of determination (R^2) of 0.9031. While scenario B found the 10-6-1 structure to be the best model with R^2 of 0.9312. Model performance for scenario A and scenario B is given in Figure 6 and Figure 7.

Scenario B was identified through the addition of 3 input parameters, namely branch number, branch diameter, and the number of leaves. The modelling results, as shown in Figure 7, showed a higher performance than scenario A, which was 0.9312 (93.1%). The model was then validated using a different dataset and obtained a model performance of 0.9381 (93.8%), as shown in Figure 8.

The model performance using scenario A in Figure 6 shows that the comparison of the predicted melon weight with the actual measurement results has a good accuracy of 0.9031 (90.3%). This means that the seven input parameters are good enough to represent the activity of predicting melon weight. This performance was validated using the latest dataset that has not been used to build the prediction model, and it was found that the model performance decreased by 5% to 0,8456 (84.6%).

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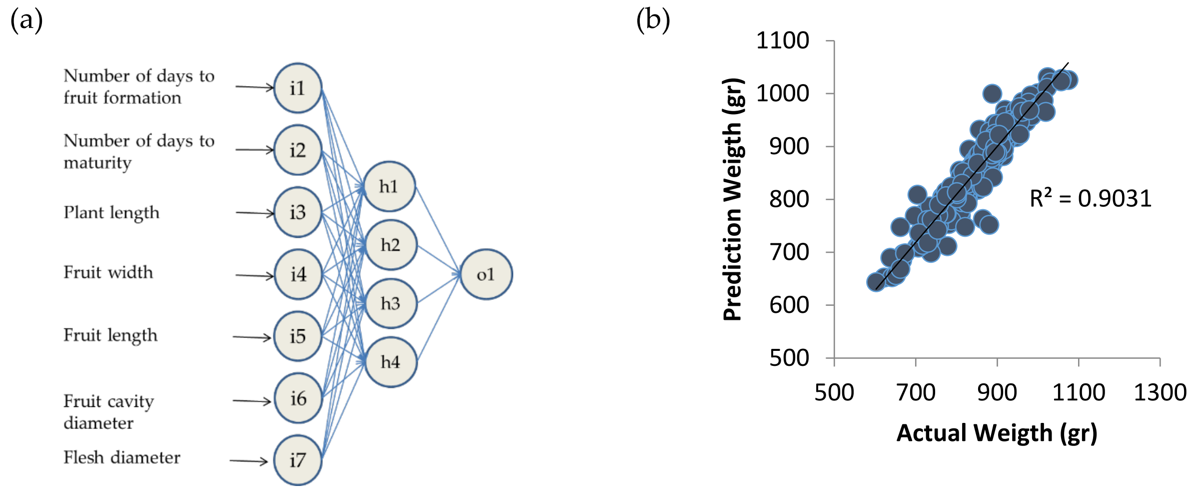

Figure 6 Scenario A prediction model (a) ANN model structure (b) accuracy model

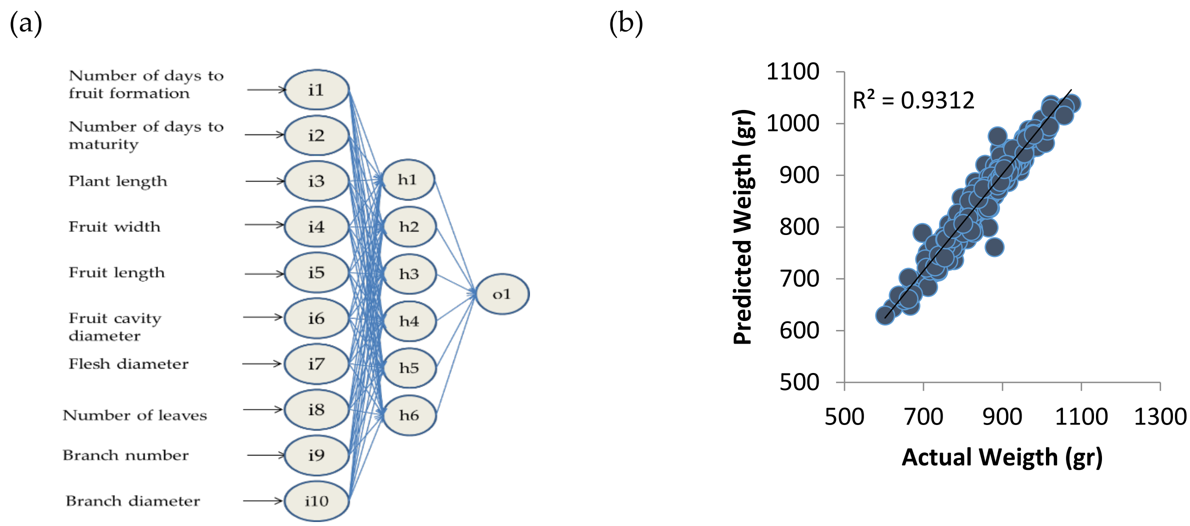

Figure 7 Scenario B prediction model (a) ANN model structure (b) model accuracy

Scenario B was identified through the addition of 3 input parameters namely branch number, branch diameter, number of leaves. The modelling results as shown in Figure 7 showed a higher performance than scenario A, which was 0.9312 (90.3%). The model was then validated using a different dataset and obtained a model performance of 0.9381 (93.8%).

The quality of melon fruit, in this case, fruit weight, is influenced by the implementation of plant cultivation that has been carried out. However, observations of plant morphology and phenology can be used as a basis for observation during the implementation of melon cultivation in the greenhouse. Hydroponic cultivation in the greenhouse is expected to produce the expected melon fruit quality. The success of hydroponic cultivation of plants in the greenhouse is influenced by: nutrient schemes

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(Yam *et al.* 2020), plant cultivation environmental factors such as solar radiation, temperature, humidity, CO2 levels, pollutants, and wind speed (Yuwono *et al.* 2014), variety factors (Firmansyah *et al.* 2018) (Pradana and Irawati 2016), and planting media factors (Nabiela and Dwi 2019) (Christy *et al.* 2018).

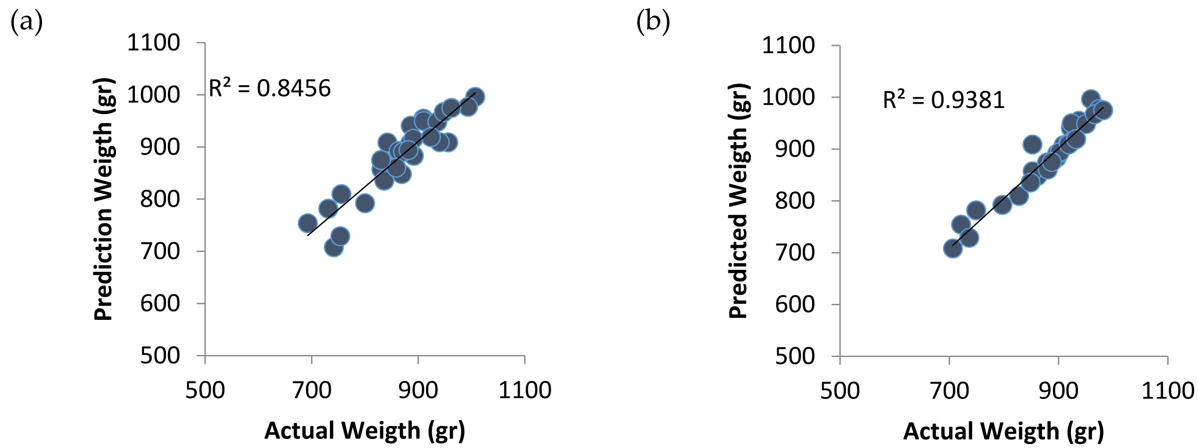

Figure 8. Comparison of predicted melon weights with actual measurements (a) scenario A (b) scenario B.

4. Conclusion

The development of a fruit weight prediction model with seven inputs and ten inputs found that fruit weight prediction using ten input parameters and fruit weight as output is the best model. The model structure was identified in the 10-6-1 pattern (10 inputs, 6 hidden and 1 output), with a prediction performance of 93.8%. The model was then validated, and the performance improved by about 0.1 (10%). Therefore, it can be said that the 10-6-1 structure ANN model is a good enough model to be used as a reference for the development of melon cultivation in the greenhouse with the ultimate target of increasing fruit weight.

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