PEMODELAN PREDIKTIF STATUS FISIOLOGIS NOKTURNAL SELADA (*Lactuca sativa* L.) BERBASIS *MACHINE LEARNING* DENGAN INTEGRASI PARAMETER FISIOLOGI TANAMAN FASE TERANG-GELAP PADA SISTEM *PLANT FACTORY*

INTISARI

Oleh:
ILVA KHAIRUNNISA
22/497260/TP/13474

Konduktansi stomata nokturnal (g_s,n) merupakan parameter fisiologis penting yang mengatur pertukaran gas dan kehilangan air pada tanaman selada (*Lactuca sativa* L.) dalam sistem *plant factory*. Penelitian ini bertujuan mengkarakterisasi pola temporal g_s,n, mengidentifikasi parameter penggerak utama, menganalisis pengaruh *memory effect* fase terang, serta membangun model prediktif berbasis *machine learning*. Pengukuran dilakukan pada tiga tanaman selada umur 28–32 HST menggunakan LI-6800 selama fase gelap (21.00–05.00 WIB) dengan interval 10 menit, serta didukung pemantauan mikroklimat menggunakan sensor Pulse Pro. Analisis data meliputi korelasi Spearman, *Variance Inflation Factor* (VIF), dan *Variable Importance in Projection* (VIP). Model prediktif dikembangkan menggunakan Ridge Regression, Random Forest, dan XGBoost dengan validasi Leave-One-Day-Out Cross Validation (LODO-CV). Hasil menunjukkan bahwa g_s,n berfluktuasi sepanjang malam dengan fenomena *predawn stomatal opening* terdeteksi pada dua dari tiga tanaman. Laju transpirasi nokturnal (En) memiliki korelasi tertinggi ($\rho = 0{,}999$; $p < 0{,}001$), namun diposisikan sebagai *performance ceiling* untuk validasi kualitas data, bukan sebagai prediktor praktis. Parameter lingkungan utama yang berkaitan dengan variasi g_s,n adalah VPDleaf dan RH, sedangkan parameter fase terang ($\bar{A}$, $ET\bar{R}$, ΦPSII, g_s,d,) berperan sebagai *memory features* dengan nilai VIP > 1,0. Model Random Forest dipilih sebagai model utama karena memberikan keseimbangan antara akurasi ($R^2 = 0{,}9789$), stabilitas antar tanaman (standar deviasi $R^2 = 0{,}0080$), dan kemampuan menangkap hubungan non-linear. Secara keseluruhan, hasil penelitian menunjukkan bahwa prediksi g_s,n yang akurat memerlukan integrasi parameter lintas skala dan fase dalam sistem *plant factory*.

Kata kunci: konduktansi stomata nokturnal, *machine learning, memory effect, plant factory*, selada

PREDICTIVE MODELING OF NOCTURNAL PHYSIOLOGICAL STATUS OF LETTUCE (*Lactuca sativa* L.) USING MACHINE LEARNING WITH INTEGRATION OF PLANT PHYSIOLOGICAL PARAMETERS IN LIGHT-DARK PHASES WITHIN A PLANT FACTORY SYSTEM

ABSTRACT

By:
ILVA KHAIRUNNISA
22/497260/TP/13474

Nocturnal stomatal conductance (g_s,n) is a key physiological parameter regulating gas exchange and water loss in lettuce (*Lactuca sativa* L.) within plant factory systems. This study aims to characterize the temporal dynamics of g_s,n, identify its main driving factors, assess the influence of daytime memory effect, and develop predictive models using machine learning. Measurements were conducted on three lettuce plants aged 28–32 days after transplanting using the LI-6800 Portable Photosynthesis System during the dark period (21:00–05:00 local time) at 10-minute intervals. Microclimate parameters were monitored using Pulse Pro sensors. Data analysis included Spearman correlation, Variance Inflation Factor (VIF), and Variable Importance in Projection (VIP). Predictive models were developed using Ridge Regression as a linear baseline, Random Forest as the primary model, and XGBoost as a comparison, with Leave-One-Day-Out Cross-Validation (LODO-CV). Results indicate that g_s,n fluctuates throughout the night, with predawn stomatal opening observed in two of the three plants. Nocturnal transpiration (En) showed the strongest correlation ($\rho = 0.999$, $p < 0.001$), but as it represents a direct physiological response to stomatal opening, it was treated as a performance ceiling for data validation rather than a practical predictor. Other key drivers include VPDleaf and relative humidity (RH). Daytime physiological parameters ($\bar{A}$, $ET\bar{R}$, ΦPSII, g_s,d,) contributed as memory features (VIP > 1.0), suggesting the presence of a within-day memory effect, albeit indirectly. Random Forest was selected as the primary model due to its balance between accuracy ($R^2 = 0.9789$), stability across plants (R^2 standard deviation = 0.0080), and ability to capture non-linear relationships. Overall, the findings highlight the importance of integrating multi-scale and multi-phase parameters for accurate prediction of g_s,n in plant factory systems.

Keywords: plant factory, lettuce, nocturnal stomatal conductance, memory effect.