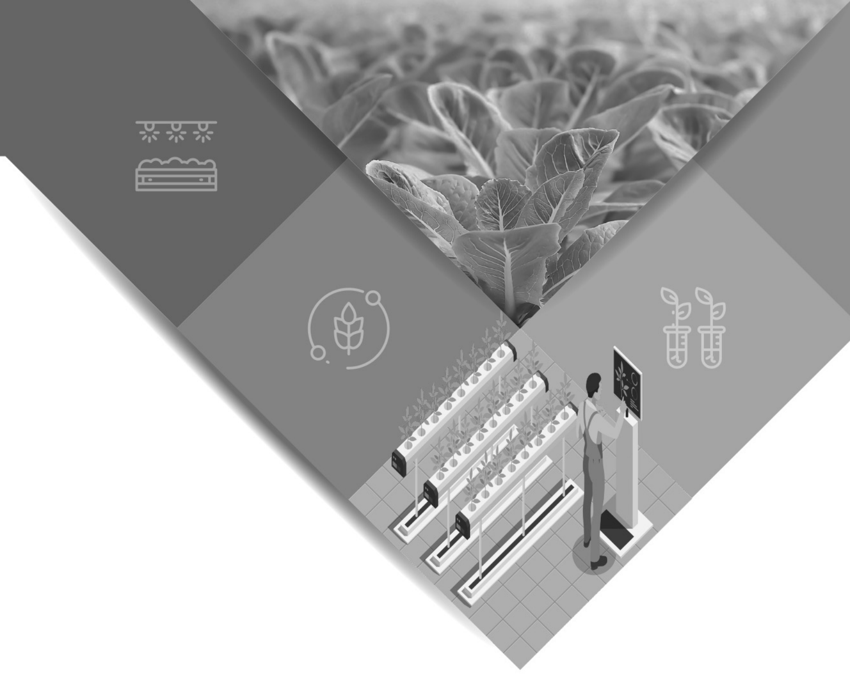

생물 분과

Bio-1

표현체 측정을 위한 장비의 다변화 전략

Diversification Strategies of Equipment for Phenotypic Measurement

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이제는 그간의 전통 육종에서 벗어나 디지털 육종과 스피드 브리딩을 실현하기 위해 "디지털 표현체 분석"을 활용하게 되면서, 기존 실험의 자동화 및 디지털화 요구가 다양해지고 있다. 1) 온도 습도 광도를 균일하게 유지하면서, 생육 상태를 매일 측정하는 방법, 2) 소형 식물체 및 과실의 이미지 취득 및 분석하는 방법, 3) 실제 재배 공간에서 생육 상태를 실시간 모니터링하는 방법 등 다양한 요구가 있으므로 각 상황에 맞는 시스템을 제작하여 보급하고 있다. 대표적으로 1) 온실에서 작물을 키우면서 온습도 관리와 다양한 카메라 & 센서를 사용하여 매일 같은 시간대에 자동으로 영상을 촬영할 수 있는 컨베이어 타입 피노타이핑시스템, 2)소형 작물 및 과실을 촬영하기 위한 캐비넷 타입 피노타이핑시스템, 3) 실외에서 자라는 식물체를 촬영하기 위한 필드 타입 피노타이핑 시스템, 4) 인공환경실 내에서 매일 영상을 취득할수 있는 X.Y.Z 타입 피노타이핑시스템을 개발하여 보급하고 있다. 하지만 이러한 시설 제작 시 연구자들의 다양한 요구사항들이 사실상 시설 설치 이후 운영에 문제가 되는 경우가 많아서 이런 내용을 공유하고자 한다. 앞으로 디지털 표현체 분석을 위한 사전 기획에 도움이 되었으면 한다.

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Bio-2

Temperature Stress Symptom Detection Using Image Processing for Seedlings of Six Vegetable Varieties Grown Under Controlled Environment

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Temperature stress poses a significant challenge to plant growth and development, exerting profound effects on agricultural productivity and crop quality. Conventionally quantifying stress levels in seedlings relied on laborious, time-consuming, and often destructive methods. However, innovative image processing techniques coupled with advanced sensor fusion offer a promising solution for the early detection of seedling stress. In this study, an image processing techniques was used to analyze the effects of temperature stress on the growth of six different seedling species cultivated in a controlled environment. Six seedlings (tomato, pepper, lettuce, pak-choi, cucumber, and watermelon) were subjected to varying temperature condition to simulate stress conditions, while growth parameters such as leaf area, color, height, and canopy temperature were monitored using RGB, thermal and depth camera over a defined period. The texture feature was extracted using the Gray-Level Co-occurrence Matrix. To select the best feature affected by temperature stress, correlation analysis, and chi-square tests were performed. Among the 32 features, 8 were selected. The study identified varied responses to temperature stress among different seedling types. Pepper and pak-choi showed strong sensitivity, cucumber exhibited moderate, and lettuce and tomato displayed intermediate responses. Stress symptoms in tomato seedlings varied from 2.96% to 70.01%, whereas in pepper seedlings, they ranged from 13.00% to 83.33%.The findings emphasized the importance of species-specific responses to temperature stress. Recognizing diverse seedling reactions to temperature stress allows growers to optimize conditions and implement effective stress monitoring. Further research on advanced image processing algorithms with machine learning techniques will contribute to seedling stress quantification and sustainable agricultural systems.

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Bio-3

온실 청경채의 엽면적 추정 기술을 적용한 증발산모델의 민감도 및 불확실성 분석

Sensitivity and Uncertainty Analysis of Evapotranspiration Models Applied with Leaf Area Estimation Techniques for Pak Choi under Greenhouse Envrionment

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시설원예 작물의 최적 관리를 위하여, 온실 내 작물의 증발산량을 정밀하게 산정하는 것이 필수적이다. 증발산 모델은 시설 내 작물의 증발산을 정밀하게 추정할 수 있지만, 입력 변수의 정확성에 크게 의존한다. 최근 딥러닝, 기계학습 등 데이터 기반 추정 기술이 발전하면서 작물 생장 변수를 비파괴적으로 예측하는 연구가 활발히 진행되고 있다. 특히, 엽면적 지수(LAI)는 증발산 모델에서 중요한 매개변수이나, 연속적인 측정이 어렵기 때문에 이미지 분석 및 데이터 분석을 활용한 기술이 개발되고 있다. 그러나 이러한 추정 기술을 실제 모델에 적용할 때는 예측값의 불확실성과 모델의 민감도를 면밀히 분석하는 것이 요구된다. 본 연구에서는 온실에서 재배되는 청경채를 대상으로 합성곱 신경망(CNN)을 이용하여 예측한 LAI를 증발산(ET) 모델에 적용하였으며, 이를 민감도 및 불확실성 분석에 활용하였다. 또한, 센서의 정확도 및 오차를 고려하여 모델의 불확실성을 평가하였다. ET 모델의 민감도 분석 결과, Stanghellini 모델이 다른 모델에 비해 LAI 오차에 가장 민감하게 반응하였다. 또한, 대부분의 증발산 모델이 광량에 가장 민감하게 반응하는 것으로 나타났다. 따라서, 추정된 입력변수를 온실 내 모델에 활용할 때는 추정 오차가 모델 성능에 미치는 영향을 평가하고, 불확실성에 대한 각 모델의 민감도를 고려해야 한다. 본 연구의 결과를 통하여, 온실 내 청경채 증산모델의 입력변수 별 오차와 이에 따른 불확실성을 평가할 수 있었으며, 이러한 분석 결과는 향후 추정 모델의 정확도 및 센서 오차의 기준을 설정하는데 활용될 수 있다.

본 연구는 산업통상자원부(MOTIE)와 한국에너지기술평가원(KETEP)의 지원을 받아 수행한 연구 과제입니다. (No. 20212020800050)

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Bio-4

Evaluation of Effects of Light Intensity and Photoperiod on Growth and Female Flowering after Early Transplanting of Grafted Cucumber Transplants

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To produce uniform and compact transplants at minimal cost in plant factory with artificial lighting (PFAL), optimal light control is essential. In this study, treatments in two experiments were conducted after the grafted union formation of cucumber transplants to identify the optimal light intensity and photoperiod, as well as to evaluate the effects of low and high light intensities at different periods in PFAL. Three cucumber cultivar scions, ‘Goodmorningbaekdadagi (GB)’, ‘Nakwonseongcheongjang (NWS)’, and ‘Shinsedae (SD)’ were grafted onto *Cucurbita ficifolia* ‘Heukjong’ rootstocks eight days after sowing. After grafted union formation, control groups were cultivated in a semi-closed greenhouse for seven days. Simultaneously, treatment groups were cultivated in a plant factory with white LEDs for the same period. In experiment 1, treatment groups were cultivated under two different light settings: three photosynthetic photon flux (PPF) levels (200, 300, and 400 $\mu mol \cdot m^{-2} \cdot s^{-1}$) and three photoperiod conditions (12, 16, and 20 $h \cdot d^{-1}$) for seven days. In experiment 2, treatment groups were cultivated under two settings: two PPF levels (LL; PPF 50 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and HL; PPF 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$) and two-period stages (early; 1-3 and late; 5-7 days) of seven days, and under PPF 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$, 16 $h \cdot d^{-1}$ for the remaining four days. The grafted cucumber transplants of both experiments were planted into a semi-closed greenhouse and cultivated for 21 days after treatment. In Experiment 1, all treatment groups had higher light use efficiency compared to the control groups and were more compact than control groups, except for 12H-200L. In both experiments, GB had fewer number of female flowers per node in the treatment groups than in the control groups compared to other cultivars. Considering the growth parameters and the number of female flowers per node, the optimal cultivation conditions were identified as 16H-300L for GB and SD, and 20H-300L for NWS. In addition, 16H-300L was the most effective condition when cultivating all three cultivars together. When the grafted cucumber transplants were exposed to LL and HL, they were more affected during the late stage than the early stage. Therefore, it is essential to be more attentive to the potential damage from LL and HL exposure, especially just before the end of the transplant production.

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Bio-5

식물 웨어러블 전자소자를 통한 전기적 실시간 생육 모니터링

Electrical Real-Time Growth Monitoring through Plant Wearable Electronic Devices

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최근 수직농장과 같은 새로운 농업환경에 대응하고, AI기술로 개선된 데이터 분석능력을 활용하기 위해 식물의 건강정보를 정확하게 측정하는 농업센서에 대한 관심이 커지고 있다. 하지만, 기존의 농업센서들은 대부분 식물에 대한 직접적 정보가 아닌 토양이나 양액, 대기와 같은 간접적인 환경센싱을 그 대상으로 한다. 현재 직접적인 식물 센싱에는 생물학적 방법과 광학적 방법이 쓰이고 있지만 대부분 전문적 설비와 데이터 처리, 긴 분석시간이 필요하다는 한계가 존재한다. 이에 대한 대안으로서. 본 발표에서는 식물 웨어러블 전자공학을 통한 전기적 실시간 식물건강 모니터링을 소개하고자 한다. 전도성고분자나 금 코팅된 생분해성 고분자와 같은 친환경 소재로 제작된 전극은 식물표면에 일체화되어 장기간 식물에 스트레스 없이 사용 가능하다. 또한 흔히 “인바디”라는 상호명으로 잘 알려진 바이오임피던스 측정법를 식물에 적용, 전기적으로 식물은 물론 식품의 건강상태를 저전력, 실시간, 비파괴적 모니터링할 수 있었다. 이러한 식물을 대상으로 하는 전자웨어러블소자와 기술은 향후 농업 및 식품, 환경 분야에 폭넓게 응용될 수 있으리라 기대되며 기존의 농업의 한계를 극복하는데 기여할 수 있으리라 기대된다.

본 연구는 한국전자통신연구원 지원 신개념선행연구사업의 초환경적 식물 재배 및 전주기적 관리를 위한 플랜트로닉스 기반 식물건강 직접모니터링 시스템 개발 과제의 일환으로 진행된 것임.

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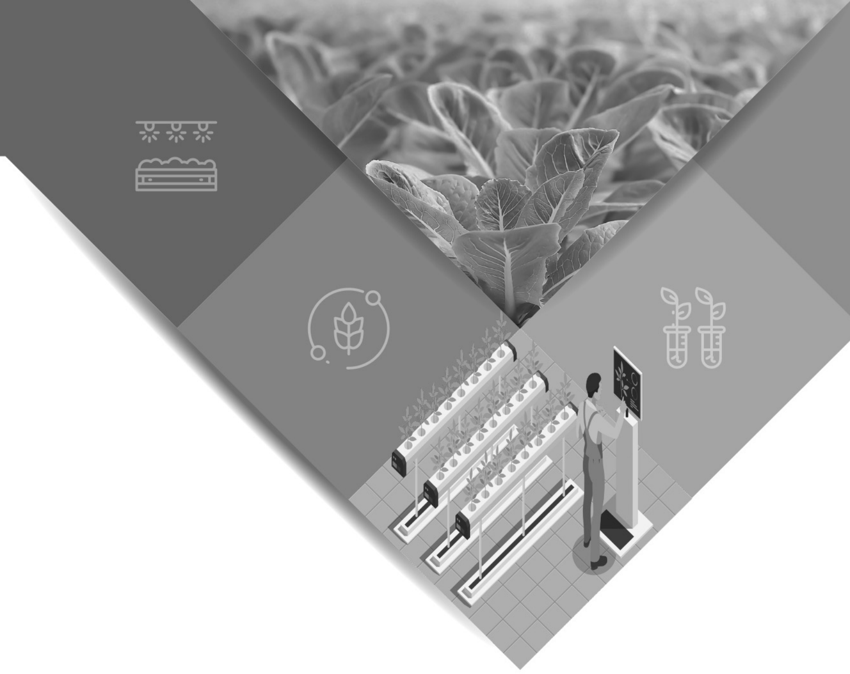

환경 분과

Env-1

DEVELOPMENT AND VALIDATION OF LOW-COST INDOOR AIR QUALITY MONITORING SYSTEM FOR SWINE BUILDINGS

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The optimal indoor environment is associated with comfortable temperatures along with favorable indoor air quality. One of the air pollutants, particulate matter (PM) is potentially harmful to animals and humans. Most of the farms have monitoring systems to identify other hazardous gases rather than PM due to the sensor cost. In recent decades, the application of environmental monitoring systems based on Internet of Things (IoT) devices that incorporate low-cost sensors has elevated extensively. The current study develops a low-cost air quality monitoring system for swine buildings based on Raspberry Pi single-board computers along with a sensor array. The system collects data using 11 types of environmental variables along with Temperature, Humidity, CO_2, Light, Pressure, and different types of Gases, PM_1, $PM_{2.5}$, and PM_{10}. The system is designed with a central web server that provides real-time data visualization and data availability through the Internet. It was tested in actual pig barns to ensure stability and functionality. In addition, there was a collocation test conducted by placing the system in two different pig barns to validate the sensor data. Overall, a scalable, portable, non-complex, low-cost air quality monitoring system was developed within 94$ successfully.

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Env-2

열풍난방기에 의한 딸기 온실 내 환경인자 분포 변화 분석

Analysis of Environmental Factor Distribution Changes in Strawberry Greenhouse due to Heater

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본 연구는 겨울철 딸기 온실 내 가온과 이산화탄소 공급을 위해 열풍기를 가동하였을 때 딸기 온실 내 구역별 환경인자(온도, 습도, 이산화탄소 농도)의 변화를 분석하기 위해 실시되었다. 환경인자 수집을 위해 온도와 습도, 이산화탄소 측정 센서(MCH-383SD, Lutron, Taiwan)을 사용하였다. 데이터 수집 기간은 열풍난방기의 가온을 필요로 하는 1월 17일부터 3월 15일까지 이며, 데이터 수집 간격은 1분이다. 데이터 분석은 전처리과정(이상치 및 결측치 제거) 후 진행되었다. 환경인자 분포 변화 분석을 하기 위한 지표로 균등계수를 이용하였다. 균등계수는 [(1-표준편차/평균)*100]으로 선행 연구의 분석방법을 인용하였고, 균등계수의 상승은 균등함을, 균등계수의 하강은 불균등해짐을 의미한다. 열풍난방기의 가동에 따른 환경인자 분포 변화 분석을 위해 데이터세트를 가동 전(오전 7시~오전 9시), 가동 중(오전 9시~오전 11시), 가동 후(오전 11시~오후1시)로 나누어 진행되었다. t-test 분석 결과, 온실 내 온도와 습도에 대한 열풍난방기 가동의 영향이 있는 것으로 나타났다($p \leq 0.05$). 하지만 이산화탄소 농도의 변화는 열풍난방기의 영향이 없는 것으로 나타났다($p>0.05$). 온도는 열풍기의 가동 전과 가동 후의 균등계수는 대체적으로 상승하여 균등해졌으며, 습도의 경우 대체적으로 낮아져 불균등해졌음을 알 수 있다. 이산화탄소 농도는 가동 전과 가동 후의 균등계수가 대체적으로 비슷하였다. 이는 열풍난방기에 의해 이산화탄소 농도 분포에 영향을 주지 못한 것으로 판단된다. 본 연구결과로 순환팬이 구비되지 않은 온실에서 열풍난방기를 통해 온실 내에 가온과 온도 분포를 균등하게 할 수 있음을 알 수 있다. 농가의 열풍난방기 선택에 도움이 될 수 있도록 온실의 종류와 크기에 따른 최적화된 열풍난방기의 용량에 대해 추후 연구가 필요하다.

본 결과물은 농림축산식품부의 재원으로 농림식품기술기획평가원의 스마트팜다부처패키지혁신기술개발사업의 지원을 받아 연구되었음(421040-04)

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Env-3

콩 수확기의 풍구 내부에 대한 CFD 유동해석

CFD Analysis of Airflow in Soybean Harvester Blower Fan

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국내 주요 곡물 소비량 중 두류의 곡물 자급률은 5.9%로 곡물 전체 자급률 20.9%에 비해 저조하다. 콩의 자급률을 올리기 위하여 개발 중인 콩 수확기는 선별 후 콩대, 콩깍지 등의 이물질 비율이 13% 이상 수집되어 생산성 저하와 추가 노동력 투입에 대한 비용 증가로 이어지고 있다. 본 연구는 콩 수확기의 선별부의 풍구 개선 설계에 앞서 풍구의 공기역학적 해석을 통해 유체의 흐름을 분석하였다. CFD 해석(ANSYS Fluent 2023 R1)프로그램을 이용하여 송풍구의 유동 해석을 진행하였다. 설계된 풍구는 길이 800mm, 폭 840mm, 높이 460mm의 크기로 설계 하였으며, 내부는 날개가 3개인 임펠러로 구성되어 있다. 임펠러의 크기는 지름 424mm, 폭 755mm이다. CFD 해석을 위해 단순화 작업된 설계 모델링을 하였으며, 해석 요인은 임펠러 회전수, 풍구 토출구 가이드 각도에 따라 해석을 진행 하였다. 해석 조건은 정상상태 해석인 MRF(Moving Reference Frame)방법으로 임펠러의 Rotating Fluid Zone을 형성하여 진행하였다. 작동 유체는 공기와 밀도는 1.204kg/m^{3}로 설정했으며, 점성 모델은 Standard k-e 모델과 Scalable Wall Function을 사용하였다. Boundary condition에서 inlet과 outlet은 대기압으로 설정하였다. 해석 결과로 토출구에서 선별이 이루어지는 안내가이드까지의 거리에서 유동속도에 따른 적절한 가이드 각도를 확인하였다. 토출구 Outlet을 기준으로 유동장의 형태는 임펠러의 회전속도가 증가 할수록 중심부위에서 유동 속도가 높게 나타났다. 또한 풍구의 적정 회전속도는 콩의 종말속도와 비행거리 등을 고려하여 선정되어야 할 것으로 판단된다.

본 결과물은 농림축산식품부의 재원으로 농림식품기술기획평가원 밭농업기계화촉진기술개발사업의 지원을 받아 연구되었음. (RS-2023-00231833)

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Env-4

Machine Learning-Based Weather Factor Prediction to Estimate Crop Evapotranspiration Using Meteorological Administration Data

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With the recent development of precision agriculture, research on estimating crop evapotranspiration for automatic irrigation is underway. However, it is very difficult to install, manage, and maintain sensors that collect data needed for irrigation decisions in agricultural fields. To solve this problem, we were trying to use machine learning to predict weather sensor values in agricultural fields using data from the Korea Meteorological Administration. The experimental data was taken from the public meteorological observation database provided by the Korea Administration's Meteorological Data Open Portal. We predicted public agency weather observation data in nearby areas with 23 types of weather data provided by local meteorological offices collected from January 1, 2021 to December 31, 2023. For data collection, hourly data from the Korea Meteorological Administration and minute-by-minute weather observation data from public institutions were collected through web crawling. The purification process was processed based on the QC flag (error classification code) provided by data web, and the public agency data for prediction was used. It was grouped by region with data from the local meteorological office closest to the agency's meteorological observation location. For the Korea Meteorological Administration data, wind direction values were sin and cos converted, and for public agency data, the range was specified by setting thresholds for each meteorological factor. The data was split 7:3 for training and validation. Machine learning models include Decision Tree (DT), Random Forest (RF), XGBoost (XGB), and Catboost. Adaboost, Linear Regression (LR), Multiple Linear Regression (MLR), and Support Vector Regression (SVR) models were used, and optimal hyperparameters were found and compared using grid search. When comparing the models, the XGB model was the best, and the regional average coefficient of determination was 0.94 for the average temperature, 0.91 for the highest temperature, 0.93 for the lowest temperature, 0.94 for the average wind speed, 0.91 for the relative humidity, and 0.88 for the average solar radiation. The six factors predicted in this experiment are the factors used in the FAO Penman-monteith calculator, which calculated evapotranspiration. This means there was no need to install environmental sensors to determine watering rates. Therefore, it will be possible to solve equipment cost, sensor management, and data management problems caused by the use of many sensors for data farming. Specifically, an irrigation algorithm necessary to reduce water usage, which has recently faced environmental and cost issues, will be developed and introduced into the field. You will be able to contribute to this.

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Env-5

온실 내 지열구조 및 히트펌프를 활용한 에너지 절감 분석

Analysis of Energy Saving by using the Geo-thermal Structure and Heatpump in the Greenhouse

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연중 평균 온도는 상승하는 경향을 보이나, 겨울의 낮은 외기는 더욱 낮아지며 양극화되는 현상을 나타낸다. 원예시설은 타 건축물 대비 상대적으로 단열성이 낮은 피복재를 이용하고 있어 단위면적당 에너지 부하가 크다. 특히, 겨울철에도 안정적으로 작물을 재배하고자 국내 온실 중 33 %가 가온을 하고 있으며 경영비의 40 %가 난방비로 소모되고 있다. 이에 온실의 에너지 수요에 대응하며 생육 환경을 유지하기 위해 적정 시스템 선정 및 용량 설계가 중요하다. 즉, 온실로 유입되는 태양 에너지를 효율적으로 활용하기 위해 불연속성 특징을 보조할 장치가 필요하다. 본 연구에서는 적은 에너지 소비로 많은 양의 가온을 하고자 가정용 공기열원 히트펌프와 지열을 조합한 축열 구조를 이용하였다. 외기가 낮은 겨울에는 히트펌프를 연속적으로 가동하되, 온실이 요구하는 최대 난방 부하보다 작은 용량의 히트펌프를 사용하고 축열조로 야간 난방을 보조하였다. 본 연구에서 설계된 시스템은 지열을 이용하여 난방하며 지하의 열기를 직접 실내로 공급함으로써 에너지 효율을 높일 수 있고, 구조가 단순 및 경량하고 축열성능을 향상시킬 수 있다. 이러한 효과를 분석하기 위해 실험 대상 온실서 동절기와 환절기에 내외부 환경값과 설비 인자들을 측정하였다. 연구 결과를 이용하여 겨울철 온실에서 소모되는 에너지 소비량을 줄일 수 있을 것으로 기대되며, 향후 동적 열전달방법을 이용하여 보조히트펌프의 용량 설계 등 연구가 필요할 것으로 보인다.

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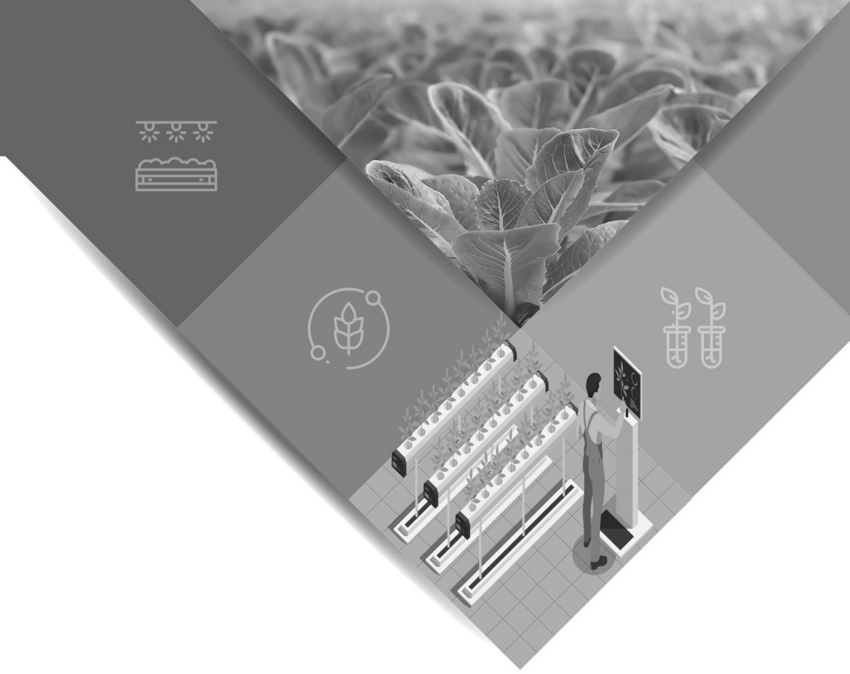

조절 분과

Con-1

Tomato seedling segmentation based on image feature and Support Vector Machine (SVM)

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Digital image processing is rapidly growing, emphasizing the need for pre-processing images before applying them to tasks like object detection and precise control for robotic applications in controlled environments. Image segmentation is an essential part of this process and requires prior knowledge of the object to extract attributes accurately, ensuring precise identification of both the object and the background. Detecting seedlings in controlled plant cultivation poses challenges due to the complex background, and background removal in adjacent seedlings when grows. In this study, a method was introduced to segment tomato seedlings, utilizing color and texture features with a support vector machine (SVM) to identify the seedlings and the background. Pepper seedlings images were captured under different lighting conditions (50, 250 and 450 μmolem^{-2}sec^{-1}). To minimize the illumination variations and emphasize the background gradient, histogram equalization and noise-removing filters were applied. Images were randomly classified into seedlings, soil, and trays categories to create a robust machine learning model. These images were then converted into 21 different color spaces for color features extraction and six texture features were obtained using a grey-level co-occurrence matrix (GLCM) algorithm. The fusion of color and texture features enhanced seedling segmentation, with optimal feature selection achieved through correlation analysis and chi-square tests. Linear discriminant analysis (LDA) decomposed the dataset into three orthogonal components, leading to accurate feature selection and significantly improved the segmentation accuracy, reaching 96% on the test set during training. The coefficient of determination (R^2) between ground truth tomato seedling and segmented seedlings was 0.97, with a root-mean-square error of 0.07. The proposed method for tomato seedling image segmentation, through color and texture features with machine learning algorithm, proved highly effective. These insights will guide optimal growth conditions and real-time monitoring in controlled cultivation across diverse environments.

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Con-2

Deep Learning Based Grading of Strawberries for Robotic Harvesting in Greenhouse Environment

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Grading plays a vital role in strawberry production, especially to meet industry or market standards and maintain uniformity in the strawberries' ripeness, appearance, and size within a batch. However, grading has been a post-harvest operation, which increases the risk of mechanical damage and fungal infection. Therefore, this study proposed a computer vision-based algorithm for grading strawberries before harvesting utilizing size, shape, and ripeness. A deep learning-based instance segmentation model, Mask R-CNN, was trained to segment strawberries and obtain the binary mask and RGB image of strawberries from which size, shape, and ripeness were identified. The final grading was performed utilizing the multi-attribute decision criteria. Three field trials were conducted in December 2023 to evaluate the performance on size estimation, shape and ripeness classification, and overall grading. The estimated size had a root mean square error of 2.94 mm compared to the ground truth measurements. Moreover, precision and recall of 0.81 and 0.82 were achieved in shape classification and 0.967 and 0.96 in ripeness classification, respectively. The proposed system achieved an accuracy of 84.5% during the final grading, showcasing its potential to aid in the robotic harvesting of strawberries, with the prospect of reducing mechanical damage and fungal infection.

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Con-3

온실 내 환경변수에 따른 딸기잎 엽록소 함량 추정

Estimation of Strawberry Leaf Chlorophyll Content according to Environmental Parameters within Greenhouses

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본 연구는 겨울철 딸기(*fragaria x ananassa*)의 품종 중 '금실(Kuemsil), 설향(Seolhyang)'의 생육 과정에 따른 엽록소 함량과 환경 변수(온도, 습도, 이산화탄소 농도, 조도)의 관계를 파악하기 위해 실시되었다. 경상남도 사천시 곤명면 은사리 42-4의 두 딸기 온실(폭 8.5m, 길이 95m, 측고 1.8m, 동고 3.5m)에서 각각 재배하며 엽록소 함량, 온도, 습도, 이산화탄소 농도, 조도에 대하여 데이터를 수집하였다. 데이터 수집 기간은 2023년 12월 20일부터 2024년 3월 15일까지이며, 데이터 수집 간격은 엽록소 함량을 주 1회 측정, 환경 데이터를 1분 간격으로 센서를 이용하여 수집하였다. 엽록소 함량은 엽록소 측정기(SPAD-502 plus, Minolta, Japan)를 이용하여 측정하였고, 온도와 습도, 이산화탄소 농도는 센서(MCH-383SD, Lutron, Taiwan)를 사용하고, 조도는 센서(LX-1128SD, Lutron, Taiwan)로 수집하였다. 상관관계 분석은 전처리 과정(이상치 및 결측치 제거) 후 진행되었다. 이후 Pearson 상관관계분석을 실시하였고, 온도는 습도와 이산화탄소 함량에 상관관계를 보였으며, 조도는 이산화탄소와 상관관계를 나타냈다. 향후 회귀모델을 이용하여 각각의 품종에 대한 환경 데이터 변화에 따른 엽록소 함량 예측 모델을 개발할 수 있을 것으로 보이며, 이는 온실 내 환경에 따른 엽록소 함량 모델링에 기여할 수 있을 것으로 판단된다.

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Con-4

Analysis of Data Collection Cycle for Carbon Dioxide Control in Strawberry Greenhouse

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The aim of this study is to determine the optimal carbon dioxide concentration control for crops in a facility greenhouse and the optimal interval for collecting environmental data on carbon dioxide concentration within the greenhouse. The greenhouse was located in Jinju, Gyeongsangnam-do, and was a strawberry 'Seolhyang' cultivation greenhouse. Eight carbon dioxide sensors (MCH-383SD, Lutron, Taiwan) were installed inside the greenhouse, and data was collected. The collected data underwent a preprocessing process for missing data handling and outlier removal. After data preprocessing, the collection intervals were changed to 1 minute, 10 minutes, 30 minutes, and 1 hour to analyze the changes in the data over time. Multivariate time series ARIMA analysis was conducted based on the collected data, and the performance of the ARIMA model according to the data collection intsserval was evaluated using R2, RMSE, MAPE, and MASE. According to the analysis, data collection at 1-minute intervals showed the best model performance with R2=0.899, RMSE=5.501, MAPE=0.472, MASE=2.448. On the other hand, as the collection interval increased, the model performance reduced, and the data collected at 1-hour intervals showed the lowest performance. By establishing the optimal data collection cycle within the greenhouse, this research provides a basic framework for managing and utilizing vast amounts of data more efficiently in the agricultural sector.

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Con-5

YOLOv5s-CGhostnet: Lightweight Improved Model for Strawberry Detection

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The development of lightweight vision algorithms is critical for the effective deployment of strawberry harvesting robots in agricultural fields. YOLO models are widely favored for their speed, accuracy, and real-time detection capabilities. However, the standard YOLO architecture suffers from drawbacks such as a large network size, high computational demands, and slow inference times. In response, the YOLOv5s-CGhostnet was introduced to enhance strawberry detection. This improved model modifies the baseline YOLOv5s architecture by replacing base modules CBS and C3 with Ghost modules GCBS and GC3 respectively, resulting in a significant reduction in model size and computational requirements. Furthermore, it adopts the SIOU loss function to refine localization accuracy and integrates CBAM attention modules for feature enhancement. These modules are strategically placed in the backbone and neck sections of the network. As a result of these enhancements, the YOLOv5s-CGhostnet achieves a higher mAP@0.5 of 91.7% while reducing model size by 85.09% and GFLOPs by 88.5% compared to the original YOLOv5. This not only improves mean average precision but also substantially decreases model size and computational overhead when compared to standard lightweight YOLO models, making it a more efficient solution for strawberry harvesting robotics applications.

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