《2026　Virtual Science Symposium Report》

"Can a Plant-Based Diet Help Save the Planet? "

Exploring Its Role in Combating Global Warming

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Abstract

As the greenhouse effect worsens, climate change has become one of the most serious problems in the world today. The large amount of carbon dioxide and other greenhouse gases in the air is causing the Earth to heat up more quickly, which is having a major impact on nature and human life. Because of this, reducing carbon emissions has become a shared goal around the world. Plants—especially vegetables—can help slow down climate change by taking in carbon dioxide through photosynthesis.

Taiwan's diverse climate and distinct seasons provide ideal conditions for growing a wide range of vegetables. By selecting suitable crops and applying natural farming methods, we can not only improve agricultural productivity and dietary health, but also enhance the carbon fixation capacity of crops—contributing positively to environmental sustainability.

This study focuses on vegetables grown in the rooftop garden on our school campus. Using seasonal crops native to Taiwan as references, we selected various vegetable species for sampling and experimental design. We conducted measurements of the vegetables' carbon fixation efficiency under illumination, aiming to compare the carbon reduction potential of different seasonal vegetables, analyze the influencing factors, and identify the most promising varieties for wider adoption. Through this, we hope to provide scientific evidence for climate adaptation and the advancement of sustainable green agriculture.

Introduction of Literature

Global warming has become one of the most pressing environmental issues of our time. According to a United Nations report, agriculture and livestock farming are responsible for about 25% of global greenhouse gas emissions. Among these, methane produced during livestock raising has a particularly strong impact on climate change.

To address this challenge, adopting a plant-based diet is considered an effective strategy. Research shows that plant-based diets can significantly lower greenhouse gas emissions. The United Nations Environment Programme (UNEP) states that switching to a plant-based diet could reduce the environmental impact of human activities by 42% to 84%—including greenhouse gas emissions, water consumption, and land use.

A study by the University of Oxford further found that if the global population adopted a vegan diet, land use could be reduced by up to 75%, which would help protect ecosystems and biodiversity. In addition to environmental benefits, reducing meat consumption can also lower the risk of heart disease, diabetes, and certain cancers. A well-planned plant-based diet can provide sufficient vitamins, minerals, and dietary fiber, supporting overall health. In Taiwan, many schools have begun promoting "low-carbon meals," encouraging students to eat vegetarian lunches once a week or once a month. These initiatives not only help reduce greenhouse gas emissions but also raise students' awareness of environmental sustainability.

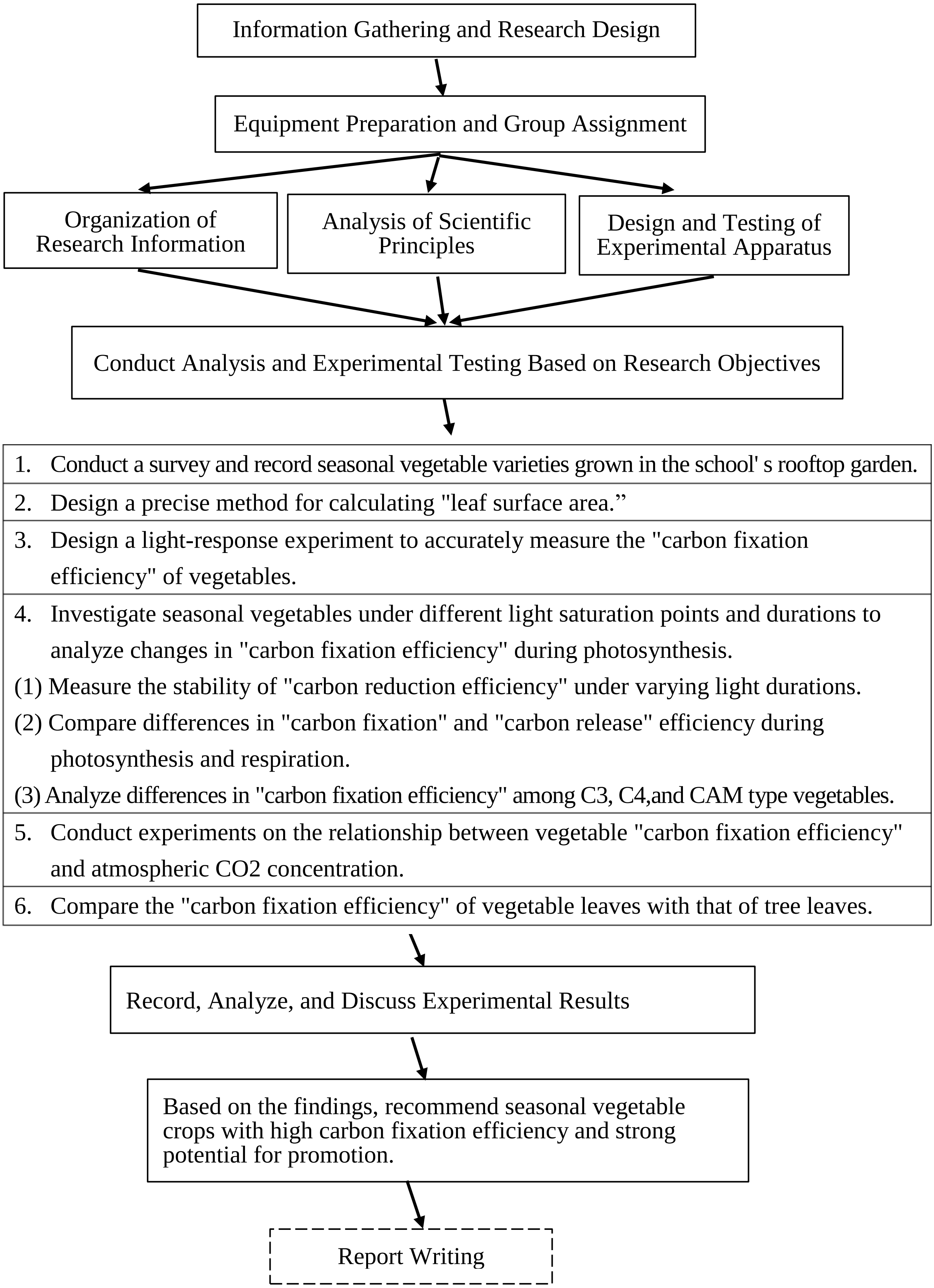
Research Questions

Since the Industrial Revolution in the 18th century, continuous emissions of industrial waste gases and carbon dioxide has led to severe climate change—such as the melting of Arctic ice, intensified desertification, and increasingly abnormal weather patterns—resulting in a sharp rise in global temperatures. In recent years, people have taken various actions to reduce carbon emissions, such as planting trees and saving electricity. If vegetables can be used as a means to reduce carbon emissions, and if the benefits of vegetable consumption are widely promoted, it could help mitigate climate issues and slow down the pace of global warming.

Therefore, this study aims to explore the following questions:

1. What is the trend of temperature change from 2020 to 2025?
2. How stable is the carbon fixation efficiency of seasonal vegetables under different durations of illumination?
3. What are the differences between the photosynthetic "carbon fixation" efficiency and the respiratory "carbon release" efficiency of seasonal vegetables?
4. How does the carbon fixation efficiency of seasonal vegetables vary across different seasons?
5. What is the relationship between the carbon fixation efficiency of vegetables and atmospheric CO_2 concentration?
6. Based on the findings, which economically valuable vegetables with high carbon fixation efficiency should be recommended for wider cultivation?
7. Which vegetables with high carbon fixation efficiency also offer high nutritional value and local availability, making them ideal for promoting low-carbon, plant-based diets?

The following is our rearch framework flowchart.



【Figure 1. Research Framework Flowchart】

Research Methods

We used observational data collected at Cianjin1 station from 2020 to 2025. We investigated the seasonal vegetable varieties grown in the school's rooftop garden and applied appropriate experimental equipment and tools to explore the carbon fixation efficiency of these vegetables. Leaf area was measured and calculated using ImageJ software.

1. The location of Cianjin1 station

   Cianjin1 station locates in Kaohsiung City, Taiwan. The terrain is plain and the climate type is tropical monsoon.

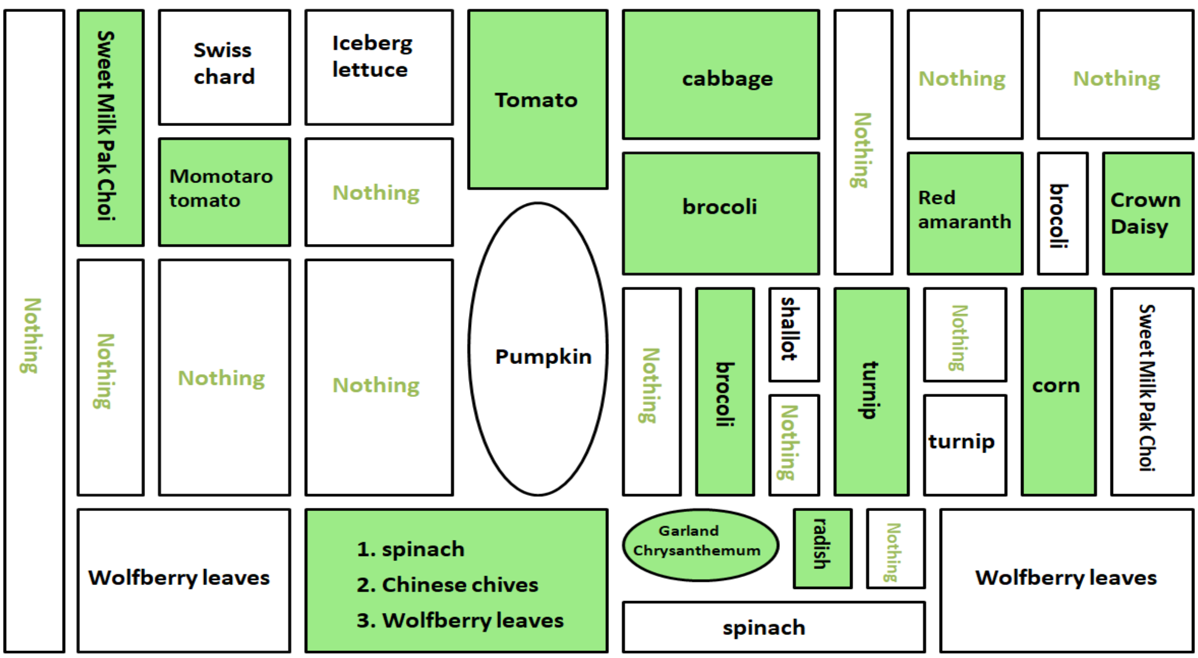
Site Information

Site ID	104218
Name	Cianjin 1
Latitude	22.630026°
Longitude	120.291204°
Elevation	6.8m
Location Source	other

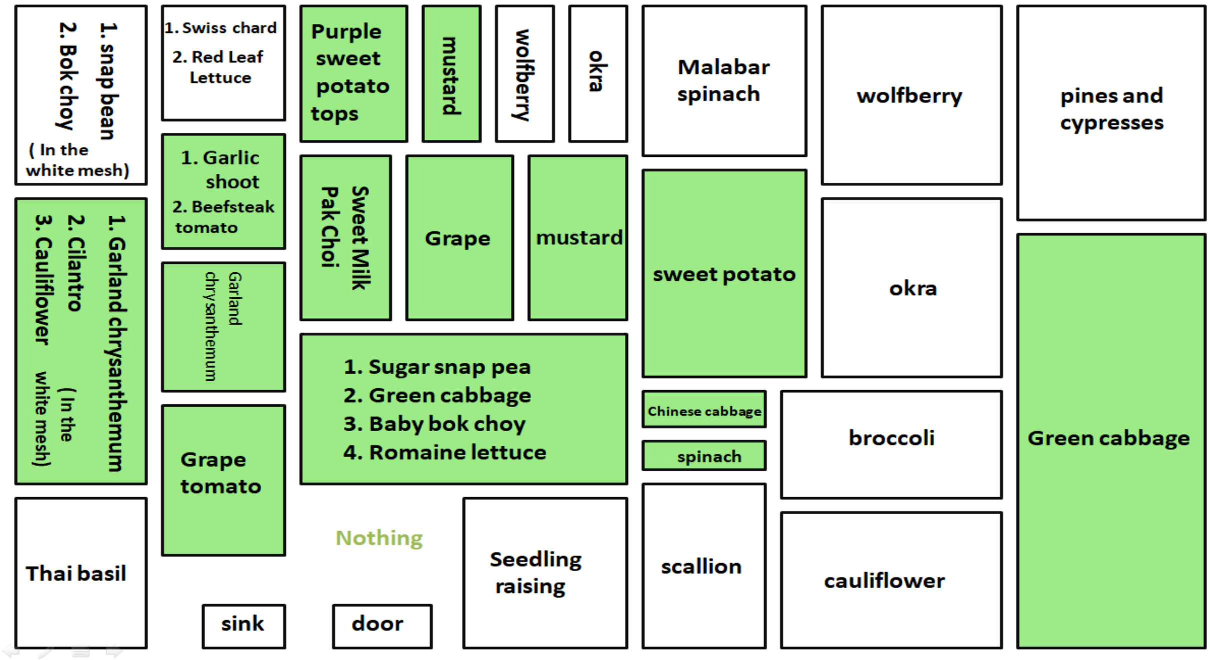
【Figure 2. the site information of the Cianjin 1 station】

2. Vegetable sampling location

Vegetable samples were collected from the rooftop garden of Cianjin Junior High School. Below are the layouts of the school's rooftop garden.



【Figure 3. Left Side of the Rooftop Garden】



【Figure 4. Right Side of the Rooftop Garden】

3. Experimental Equipment and Tools

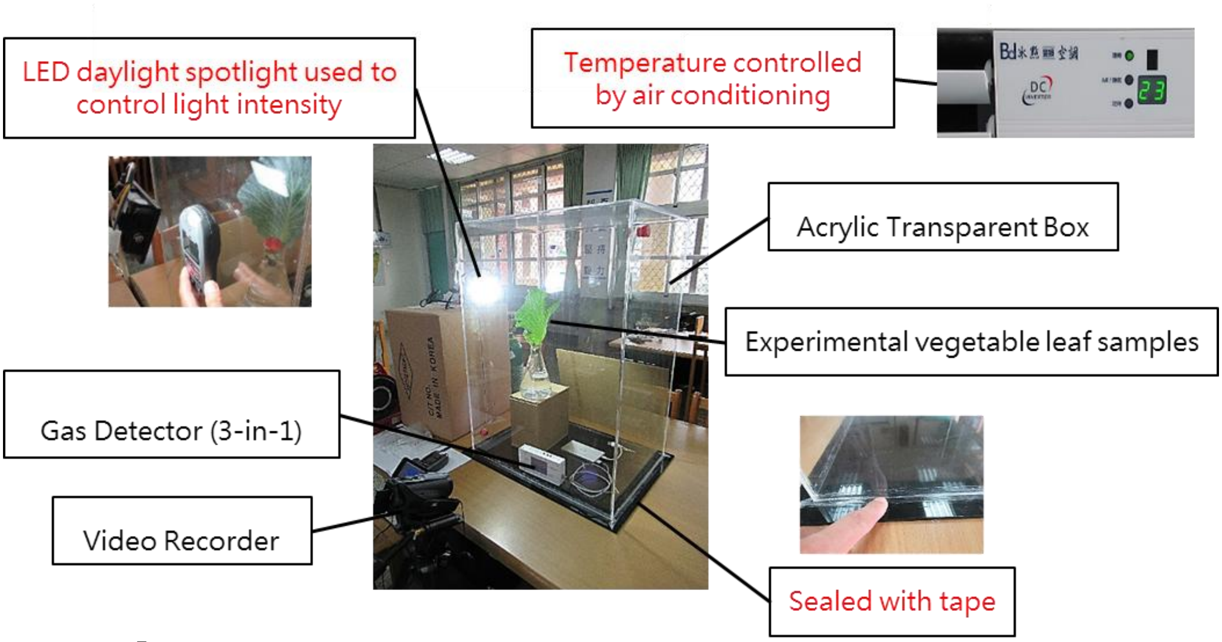
Below are the equipment and tools we used to conduct the experiment on the carbon fixation efficiency of these vegetables.

(1) All-in-One Printer : Scanned images of  vegetable leaves were used to calculate the area using computer software.	(2) Lux Meter : Used to measure the  illuminance of the experimental light source illuminating the vegetables.
(3) Gas Detector (3-in-1): Used to measure  temperature, humidity, and CO_2 concentration in the air of the experimental chamber (dependent variables).	(4) Acrylic Transparent Box (with Light   Cover): Used to control the environmental air volume at 122.5 L, providing transparent conditions for photosynthesis experiments and light-blocked conditions for respiration experiments.
(5) LED Daylight Projector Lamp (with Stepless Adjustment Switch): 30W, 50W,  100W, 200W, and 400W / 100V LED lights were used as light sources for photosynthesis experiments, allowing precise control of light intensity as an experimental variable.	(6) CO_2 High-Pressure Cylinder: Used to  manipulate the CO_2 concentration in the experimental air as an independent variable.
(7) Video Recorder: Used to record the  changes in CO_2 concentration in the ambient air, which is the dependent variable.	(8) Digital Thermometer: Used to monitor  the daily maximum and minimum temperatures.
(9) Air Conditioner: Used to control the air  temperature of the experimental environment, maintaining it between 23.0 °C and 25.0 °C (controlled variable).	(10) Rain Gauge: Used to measure the total  accumulated rainfall over the course of a day.

【Figure 5. Experimental equipment and tools】

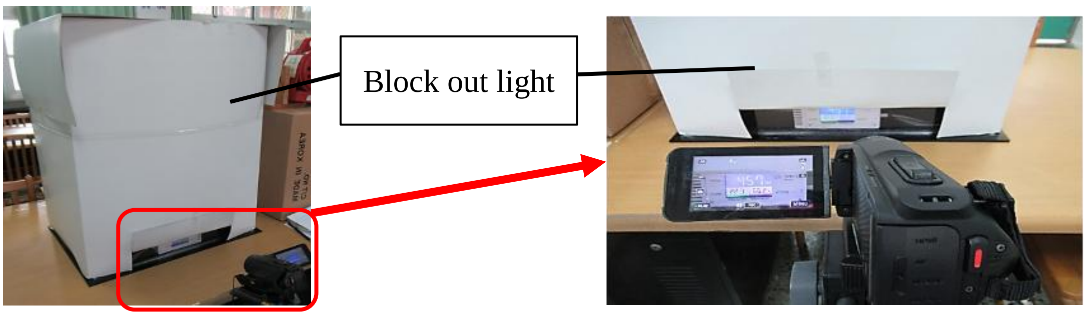
4. Experiment on Measuring the Carbon Fixation Efficiency of Photosynthesis in Vegetables

The diagram below illustrates how we conducted the experiment to measure the carbon fixation efficiency of photosynthesis in vegetable plants.



【Figure 6. Diagram of the experimental setup for measuring the carbon fixation efficiency of photosynthesis in vegetables】

The setup shown below was used to measure the respiration rate of vegetable plants by blocking light to stop photosynthesis. The light-blocking cover ensured that any changes in CO_2 concentration were solely due to respiration. A side opening at the base allowed the video recorder to monitor CO_2 levels inside the cover without allowing light to interfere with the experiment.



【Figure 7. Diagram of the respiration experiment with a light-blocking cover installed】

【Figure 8. Diagram of the light-blocking cover with a side opening at the base for video recording 】

5. Calculate Leaf Area

After completing the carbon fixation efficiency experiment, we collected the vegetable leaf samples for analysis. Measuring leaf area is important because it standardizes the photosynthetic surface across different plants, allowing for more accurate comparisons of carbon fixation efficiency. We used ImageJ software to calculate the leaf area. The steps below explain how we used ImageJ to perform this calculation.

Step 1: Prepare a Template

Place a scale bar next to the leaf samples to provide a reference for measurement.

Step 2: Scan Leaf Samples

Use the all-in-one printer to scan images of the leaves along with the scale bar.

Step 3: Set the Scale in ImageJ

Import the scanned image into ImageJ and set the scale to define the measurement units.

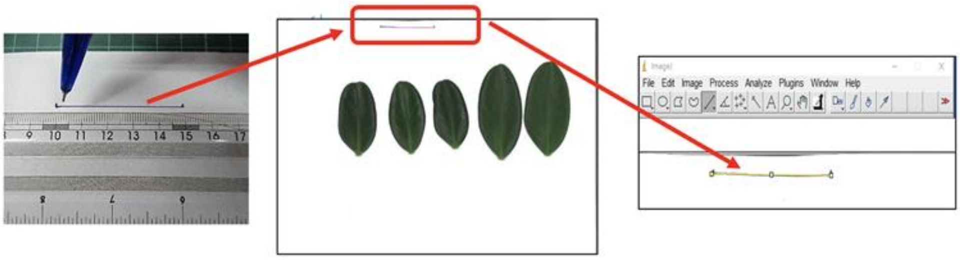
Step 4: Select the Leaf Area

Adjust the threshold settings to fill the leaf areas with red (as shown in Figure 11.) This highlights the region ImageJ will analyze.

Step 5: Calculate Leaf Area

Use the Analyze function in ImageJ to calculate the total leaf area.

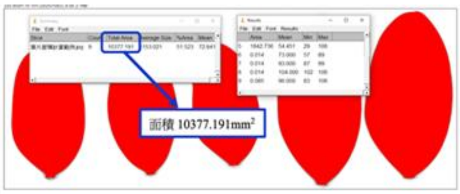
As shown in Figure 13., ImageJ can isolate and measure only the green (photosynthetically active) parts of the leaf, improving accuracy in photosynthesis-related studies.



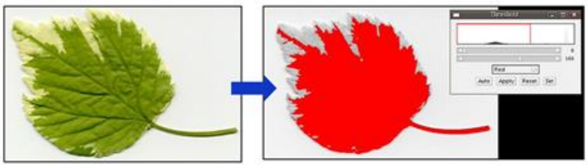
【Figure 9. Diagram of the scanned leaf sample template with a scale bar for reference】

【Figure 10. Setting the image scale bar in ImageJ】

【Figure 11. Selecting the leaf area for image analysis】



【Figure 12. Calculating the total leaf area using ImageJ】



【Figure 13. Measuring only the green (photosynthetically active) parts of the leaf】

6. Experimental Procedures

To measure the carbon fixation efficiency of photosynthesis in seasonal vegetables, we conducted a controlled indoor experiment using a sealed acrylic transparent box, artificial lighting, and gas concentration monitoring equipment. The following steps outline the complete experimental process:

(1) Collect Leaf Samples

Go to the school’s rooftop garden to collect seasonal vegetable leaf samples. Wash and dry the leaves, then insert them into conical flasks filled with water to keep them fresh during the experiment.

(2) Set Indoor Temperature

Turn on the indoor air conditioner and maintain the room temperature between 23.0 °C and 25.0 °C to ensure a stable environment.

(3) Set Up the Experimental Box

Place the prepared leaf samples and the three-in-one gas detector on the base. Cover the setup with an acrylic transparent box and seal the edges with tape to prevent external air from entering.

(4) Illuminate the Samples

Turn on the LED projector lamp and adjust the illumination to approximately 22,000 lux to simulate sunlight. Use a video recorder to continuously record the gas detector’s display panel for 2 hours.

(5) Scan and Measure Leaf Area

After 2 hours, remove the leaf samples. Cut off the leaves and scan them using an all-in-one printer. Calculate the leaf area using ImageJ software.

(6) Record CO_2 Concentration

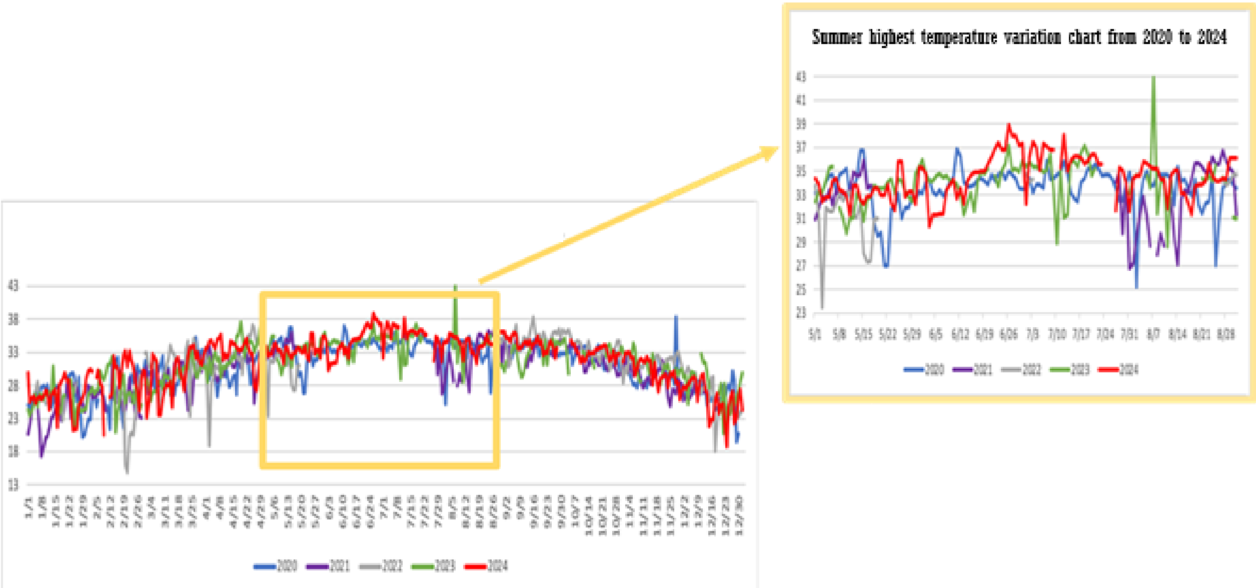
Review the recorded video and document the CO_2 concentration values at 5-minute intervals.

(7) Repeat the Experiment

Repeat steps (1) to (6) for a total of three trials to ensure the accuracy and reliability of the data.

Research Results

1. Temperature Change Trends from 2020 to 2024



【Figure 14. Highest temperature variation chart for the years 2020-2024】

After analyzing the daily maximum temperature trends from 2020 to 2024, we observed that although each year exhibited clear seasonal patterns, the frequency of abnormal climate events increased steadily. This indicates the growing impact of global warming on climate stability.

- **2020**: Temperatures remained relatively stable throughout the year, with only minor fluctuations in early spring and late winter. This year can be considered a typical climatic baseline.
- **2021**: An unusual drop in summer temperatures occurred in August, possibly due to increased rainfall or typhoon activity, indicating localized weather anomalies.
- **2022**: This year exhibited the most dramatic temperature fluctuations, particularly during spring and autumn. The wide temperature variations reflected increased climate instability.
- **2023**: Although 2023 was generally stable, a sharp temperature spike exceeding 40 °C occurred in mid-August, likely due to a heatwave. This poses risks to both ecosystems and human health.
- **2024**: The warming trend became most apparent. High summer temperatures persisted for an extended period, while extreme low temperatures were virtually absent. The overall pattern suggests that the climate is becoming not only warmer but also more homogenized.

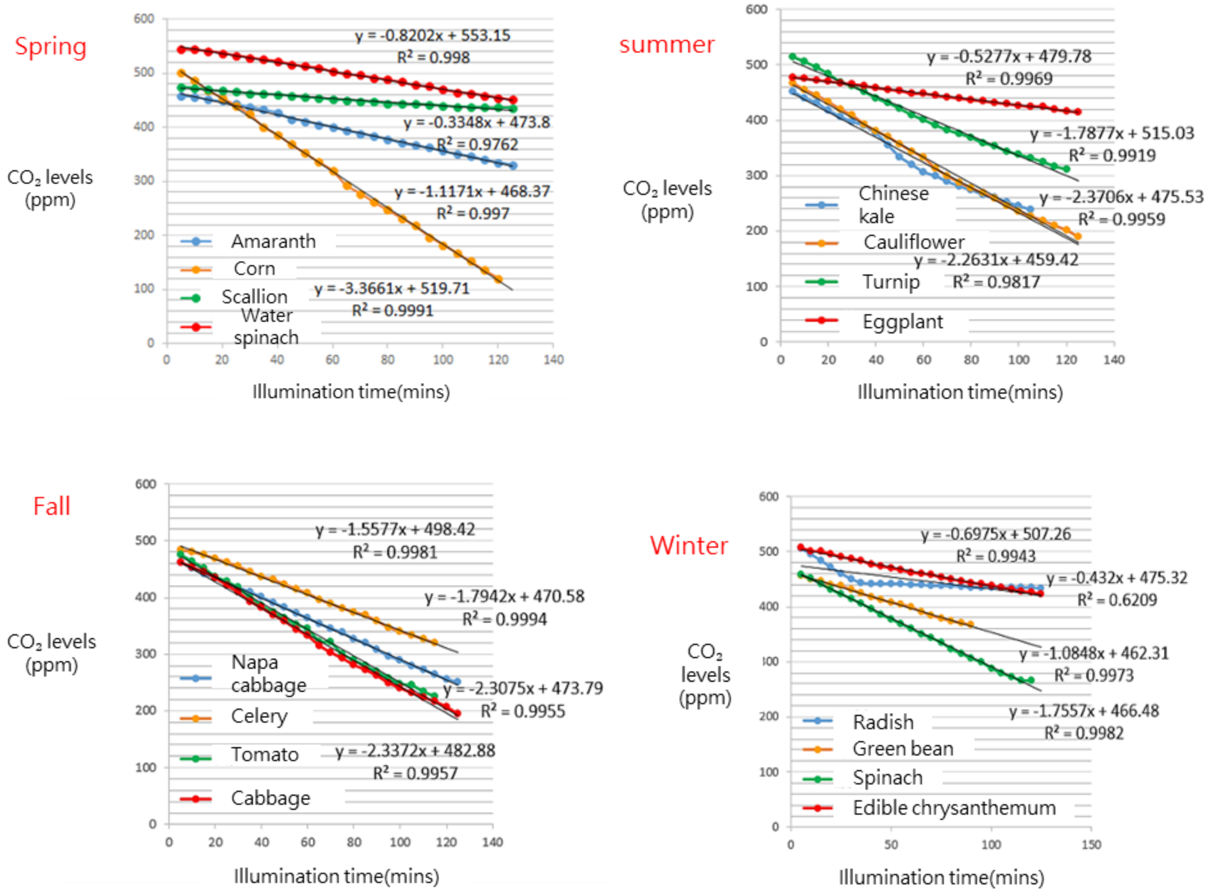
In summary, these observed changes reflect the cumulative effects of climate change and highlight the urgent need for continuous climate monitoring and strategic planning to mitigate future risks.

Year	Features by year	Temperature spike	anomaly	Summer temperature characteristics	Winter temperature characteristics	Overall Review
2020	Seasonal changes are normal	About 33°C	Slight fluctuations in March and December	Consistently stable (30–33°C), with no extreme heat events recorded	Clearly cooler conditions, about 18–24°C, with intermittent cold waves	Climate is relatively stable.
2021	Moderate climate change	No obvious spikes	Unusual drop in August	Temperatures in August fell below 25°C, causing the summer to be relatively cool.	Similar to 2020, with less volatility	Abnormal weather disturbance events occurred.
2022	Severe fluctuations	About 34°C	Sharp temperature drops occurred in February, August, and October.	Parts of the time were above typical values	Pronounced cold-hot cycles leading to high temperature variability.	An extreme climate year affecting crops and ecological systems.
2023	Stable climate but with episodes of extreme heatwaves	Over 40°C (August)	The heatwave event occurred in mid-August.	Most summer days were normal, but extreme heat peaks occurred.	Close to normal, but with a slight warming trend.	Heatwave alert year, indicating increased risk of extreme high temperatures
2024	Year with the most significant warming trend	About 36°C	Almost no abnormal fluctuations	Prolonged periods of high heat, resulting in clearly warmer and stable summers.	In winter, temperatures hovered around 25°C, with few cold spells observed.	Marked warming trend with elevated and stable temperatures across all seasons.

【Figure 15. Temperature Change Trends from 2020 to 2024】

2. **Investigation of the Stability of Carbon Fixation Efficiency in Seasonal Vegetables across Different Light Exposure Durations**

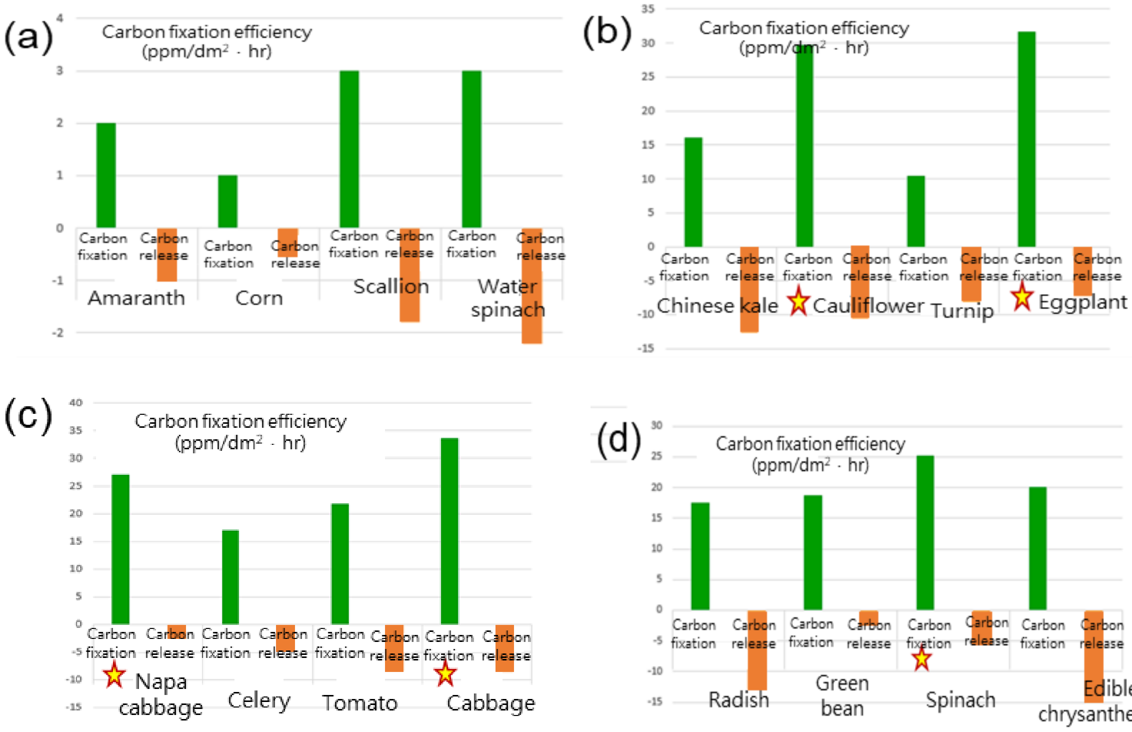
For seasonal vegetables undergoing photosynthesis, changes in CO_2 concentration within the quantitative air (inside the acrylic transparent box) over the exposure period were analyzed using linear regression. Most determination coefficients (R^2 values) exceeded 0.99, indicating a strong linear relationship. These results demonstrate that seasonal vegetables maintain stable carbon fixation efficiency across different durations of light exposure.



【Figure 16. Changes in CO_2 concentration over time in quantitative air during the photosynthesis of seasonal vegetables across the four seasons.】

3. **Comparison of Photosynthetic Carbon Fixation Efficiency and Respiratory Carbon Emission Efficiency in Seasonal Vegetables**

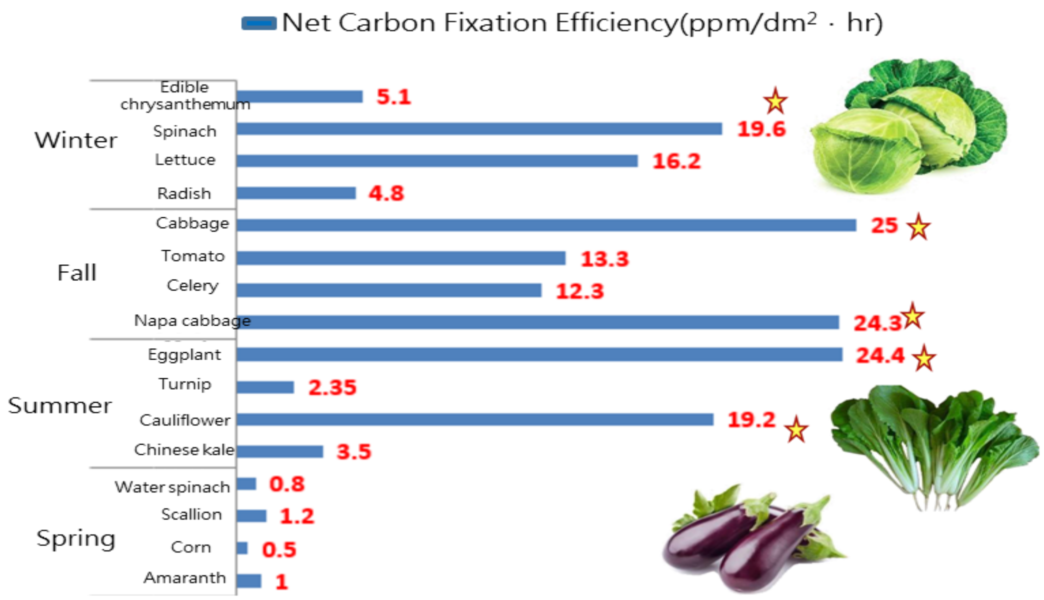
The photosynthetic carbon fixation efficiency of seasonal vegetables was found to be greater than their respiratory carbon emission efficiency. This suggests that cultivating seasonal vegetables using natural farming methods is a practical and feasible approach to absorbing atmospheric CO_2 and mitigating the effects of global warming.



【Figure 17. Comparison of photosynthetic carbon fixation efficiency and respiratory carbon emission efficiency in seasonal vegetables: (a) spring, (b) summer, (c) fall, (d) winter.】

4. Exploration of Differences in Carbon Fixation Efficiency of Seasonal Vegetables Across the Four Seasons

The photosynthetic net carbon fixation efficiency of seasonal vegetables was relatively low in spring and higher in autumn. This study suggests that environmental conditions characterized by moderate sunlight, adequate moisture, and optimal temperatures are more conducive to efficient photosynthetic carbon fixation in vegetables. These findings may serve as a valuable reference for farmers when planning the cultivation of seasonal vegetables.

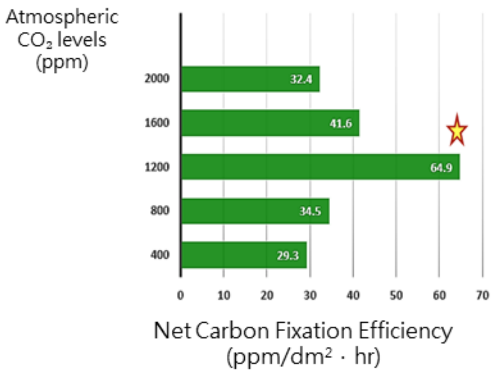


【Figure 18. Net carbon fixation efficiency statistics of seasonal vegetables. 】

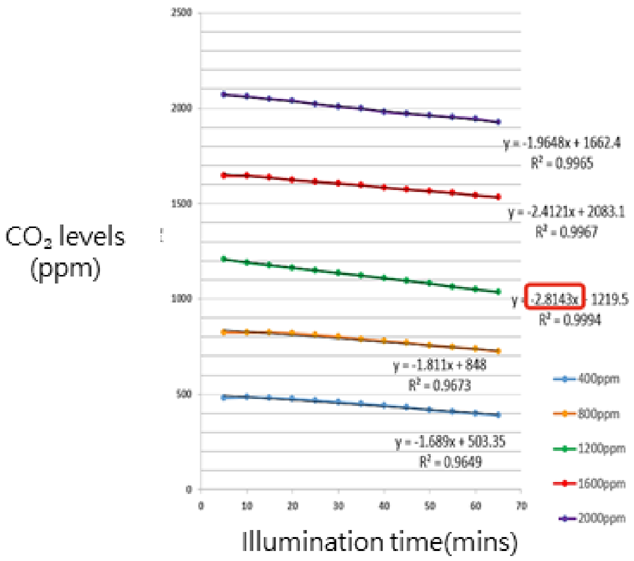
Image sources for vegetables: https://ixintu.com/sucai/7NNqjPjeP.html

5. Exploration of the Relationship Between Vegetable Carbon Fixation Efficiency and CO_2 Concentration in Air

This study used cabbage as the test sample and increased the CO_2 concentration in a fixed volume of air (122.5 L) to examine the relationship between its carbon fixation efficiency and the initial CO_2 concentration. The results showed that as the initial CO_2 concentration increased, the carbon fixation efficiency of the vegetable also increased. However, beyond a certain concentration, further increases in CO_2 led to a gradual decline in carbon fixation efficiency. These findings suggest that when atmospheric CO_2 levels exceed a specific threshold, the carbon fixation efficiency of vegetables no longer improves and may begin to decrease.



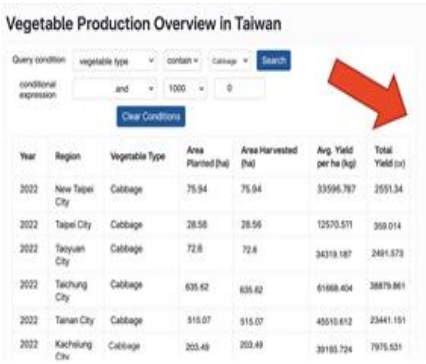
【Figure 19. Net carbon fixation efficiency of cabbage at varying CO_2 concentrations.】



【Figure 20. Temporal changes in airborne CO_2 concentration during cabbage photosynthesis under different initial CO_2 levels.】

6. Summary of Research Results and Recommendations for Promoting the Cultivation of Economically Valuable Vegetables with High Carbon Fixation Efficiency

Based on vegetable planting area statistics from 2022, the proportions of various vegetable crops and their corresponding net carbon fixation efficiencies were calculated. The data show that cabbage has the largest planting area (approximately 16%), indicating its high popularity among consumers. This is followed by Chinese cabbage (around 10%), and both green onions and tomatoes (each about 7%). Therefore, cabbage and Chinese cabbage—which currently demonstrate relatively high carbon fixation efficiency—already occupy significant portions of Taiwan's vegetable production. If conventional farming methods or organic cultivation continue to be adopted, this could further support the cultivation of economically valuable vegetable crops that are both popular and efficient in carbon fixation.


Vegetable Production Overview in Taiwan

Query condition: vegetable type | contain | Cabbage | Search

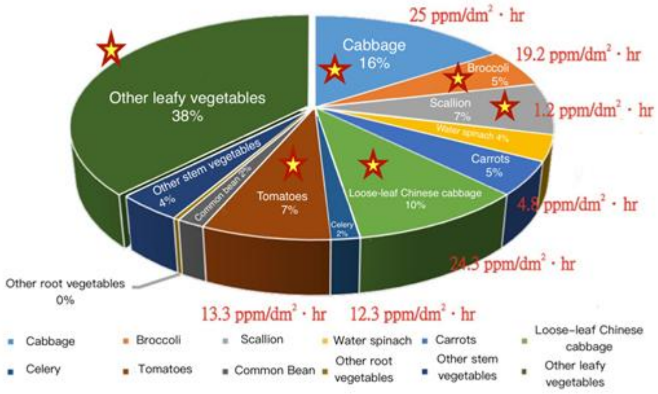
conditional expression: and | 1000 | 0

Clear Conditions

Year	Region	Vegetable Type	Area Planted (ha)	Area Harvested (ha)	Avg. Yield per ha (kg)	Total Yield (ut)
2022	New Taipei City	Cabbage	75.94	75.94	33596.787	2551.34
2022	Taipei City	Cabbage	28.56	28.56	12570.511	359.014
2022	Taoyuan City	Cabbage	72.6	72.6	34319.187	2491.573
2022	Taichung City	Cabbage	635.62	635.62	61668.404	38879.861
2022	Tainan City	Cabbage	515.07	515.07	45510.612	23441.151
2022	Kaohsiung City	Cabbage	203.49	203.49	39193.724	7975.531

【Figure 21. Open data platform map showing an overview of vegetable production in Taiwan. 】

Source: https://data.coa.gov.tw/open_search.aspx?id=113



【Figure22. Chart of vegetable cultivation area and net carbon fixation efficiency in Taiwan, 2022. 】

Source: https://data.coa.gov.tw/open_search.aspx?id=113

7. **Identifying Vegetables with Both High Carbon Fixation Efficiency and Nutritional Value for Promoting a Low-Carbon, Plant-Based Diet**

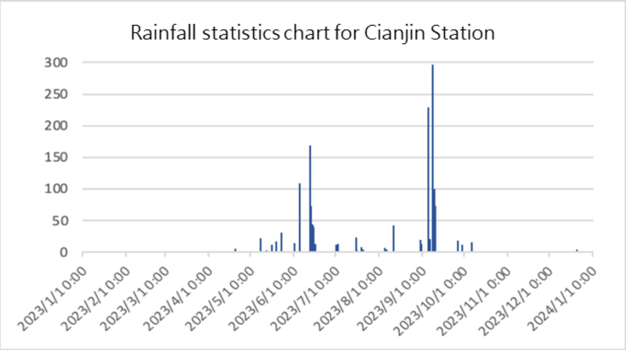
Vegetables with high carbon fixation efficiency include spinach and lettuce in winter; cabbage and napa cabbage in autumn; and eggplant and green cauliflower (broccoli) in summer. Among these, spinach, cabbage, bok choy, and green cauliflower are also rich in nutritional value, making them strong candidates for promoting a plant-based diet that supports both human health and carbon reduction.

【Figure23. Vegetable nutrition chart. 】

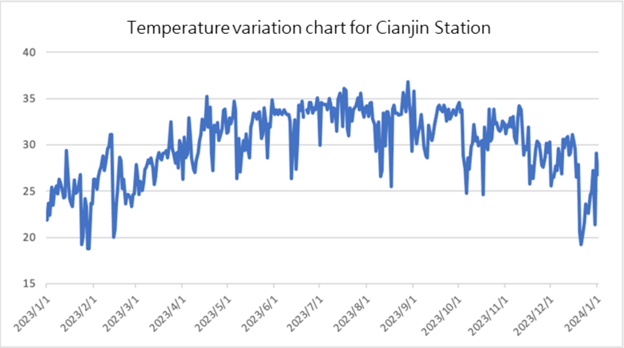
Reference source: https://health.ltn.com.tw/article/breakingnews/3517746

Discussion

Various fruits and vegetables have distinct growing seasons and location requirements, each depending on suitable temperature, moisture, and sunlight for healthy development. This study was conducted at the Cianjin Station in southern Taiwan, a region characterized by a tropical monsoon climate—featuring hot, rainy, and sunny summers and cooler, drier winters. Using digital thermometers and rain gauges, we recorded changes in temperature and precipitation throughout the year and generated statistical charts (see Figure 24 and Figure 25) to support our analysis. Based on local climate conditions and the suitability of vegetable types, this study proposes recommendations to promote the cultivation of appropriate fruits and vegetables.
(Reference: https://kmweb.moa.gov.tw/knowledgebase.php?id=19740)



【Figure 24. Precipitation Statistics Recorded at Cianjin Station from 2023 to 2024】



【Figure 25. Chart of Temperature Variation at Cianjin Station from 2023 to 2024】

According to data from the Agricultural Knowledge Database, water spinach (Ipomoea aquatica) and amaranth exhibit strong tolerance to wet conditions and thrive during periods of heavy rainfall. In contrast, crops such as lettuce, garland chrysanthemum, bok choy, and Chinese kale are less resilient in high-moisture environments. Therefore, planting water spinach and amaranth during the rainy season in southern Taiwan can help reduce the risk of crop loss.

In terms of sunlight requirements, vegetables such as Chinese cabbage, mustard greens, radish, celery, spinach, and lettuce are classified as long-day crops, requiring extended daylight hours for optimal growth. In contrast, amaranth and water spinach are short-day crops that thrive under reduced daylight conditions. Intermediate-day crops, including tomatoes and green beans, can flower under both long and short day lengths. Therefore, in regions with abundant sunlight, it is advisable to prioritize the cultivation of long-day or intermediate-day vegetables to maximize productivity and promote healthy plant development.

Conclusion

1. The maximum temperatures in winter remained relatively stable from 2020 to 2024, while summer temperatures increased gradually each year and occasionally reached abnormally high levels, indicating the impact of global warming.
2. Seasonal vegetables in all four seasons exhibited stable carbon fixation efficiency in relation to illumination duration, with most linear regression determination coefficients (R^2) exceeding 0.99. This indicates that, through natural evolution, seasonal vegetables have developed adaptability to varying climatic conditions, ensuring consistent carbon fixation efficiency year-round.
3. The photosynthetic carbon fixation efficiency of vegetables across all seasons is greater than their respiratory carbon emission. Therefore, cultivating seasonal vegetables using natural farming methods—allowing them to absorb atmospheric CO_2 through photosynthesis—represents a truly feasible strategy for mitigating global warming.
4. Cauliflower and eggplant in summer, cabbage and napa cabbage in autumn, and spinach in winter demonstrated high net carbon fixation efficiency. These vegetables may be especially effective in reducing carbon emissions and contributing to the mitigation of global warming.
5. As atmospheric CO_2 concentrations rise due to climate change, the carbon fixation efficiency of vegetables also increases. Therefore, cultivating seasonal vegetables can serve as an effective strategy for reducing carbon emissions under the current greenhouse effect.
6. In recent years, organic vegetables have become Taiwan's most economically significant crop, with a planting area surpassing that of staple foods such as rice. Given the essential role of food in daily life and the need to balance market supply and demand, promoting vegetables with high carbon fixation efficiency is strongly encouraged. This approach not only supports healthy eating and revitalizes agriculture but also helps mitigate global warming.
7. Many factors in the natural climate and environment change over time, influencing the photosynthesis and respiration of vegetables. While this study included experimental measurements, the results are subject to inevitable experimental errors and limitations.
8. This study conducted sampling experiments only on existing Taiwanese seasonal vegetables grown in the school's rooftop garden. However, Taiwan has a rich diversity of vegetable crops. In the future, further experiments can be conducted on a wider range of seasonal vegetables, with improved experimental design in response to atmospheric changes and to reduce sources of error. Continued research in this area may strengthen the role of vegetables as valuable contributors to carbon emission reduction.

Citations

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《Optional Badges》

I Am a Collaborator

This research project was completed collaboratively by a team of three members, with each person taking responsibility for specific tasks, including literature review, vegetable leaf collection, experimental setup, and data analysis. Throughout the process, we worked closely together, divided tasks fairly, and maintained clear and effective communication. Our strong teamwork and collaborative efforts demonstrate that we fully meet the criteria for the Collaborator badge.

I Work with a STEM Professional

This research falls within the fields of environmental science and plant biology and explores how vegetable photosynthesis contributes to mitigating global warming. Throughout the project, we collaborated with a STEM professional—our science teacher—who has extensive experience in scientific research and has conducted multiple science research projects. He provided guidance on research design, advised us on applying appropriate statistical methods, and helped us interpret our experimental results more accurately. Under his mentorship, we learned to properly use scientific equipment such as gas detectors, LED light sources, and ImageJ software, which helped improve the precision and reliability of our data. This collaboration enhanced our research methodology and supported more careful analysis and interpretation of results, fulfilling the criteria for the STEM Professional badge.

I Am a Data Scientist

We selected this badge because our research involved collecting and analyzing a large amount of experimental data, including CO_2 concentration changes, vegetable leaf area, and light conditions. We also integrated this with government open data—such as vegetable planting areas—for comparative analysis and inference. In addition, we evaluated data reliability, identified potential sources of experimental error, and proposed improvements. These practices align well with the selection criteria for the Data Scientist badge.