Leaf Photosynthesis of Plants under Different Precipitation Changes

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A. Overview Information

TITLE: Soil Respiration at TSU wetland

ABSTRACT: Students investigate the effects of precipitation changes on switchgrass leaf photosynthesis using a Li-Cor 6400 Portable Photosynthesis System at TSU Agricultural Research and Education Center. Students will be introduced to the rational and design of the field precipitation experiment and field facility. Students will learn how to measure leaf photosynthesis, and as groups, measure leaf photosynthesis of switchgrass growing under different precipitation treatments. Students need to read a Powerpoint presentation on the use of LiCor 6400, lean the theory of the measurements, and conduct leaf photosynthesis measurements. They will analyze data, and write a lab report as homework.

KEYWORD DESCRIPTORS

- **Ecological Topic Keywords:** carbon dioxide, climate change, precipitation change, greenhouse effect, carbon fixation, photosynthesis
- **Science Methodological Skills Keywords:** data collection and analysis, experimental design, field work, formulating hypotheses, graphing data, scientific writing
- **Pedagogical Methods Keywords:** cooperative learning, group work assessment, guided inquiry, open-ended inquiry, peer evaluation, project-based teaching

CLASS TIME: Three-hour lab sessions (plus one lecture period).

OUTSIDE OF CLASS TIME: Students will spend 4 to 6 hours, primarily writing up the associated draft and final lab reports.

STUDENT PRODUCTS: Lab report (3-5 pages)

SETTING: This experiment is designed for switchgrass system, but can be used in other ecosystems, such as wetlands, grassland, and forests.

COURSE CONTEXT: This experiment can be used in a freshman-level introductory Biology course and in an upper-level Ecology course.

INSTITUTION: Four-year, public, primarily undergraduate institution.

TRANSFERABILITY: This lab requires a Li-Cor 6400 equipment. With this equipment, this lab is very flexible and is easily translatable to larger or smaller class sizes and to non-majors classes. It can be adapted for use in gardens, and lawns. It can also be used indoors or in a greenhouse with house plants.

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B. Synopsis of Lab Module

Principal Ecological Question Addressed: How do climate change, particularly precipitation, influences leaf photosynthesis of switchgrass?

What Happens: Before the lab meets, students read about leaf photosynthesis (lecture on leaf photosynthesis is provided), the global carbon cycle, and how the Li-Cor 6400 can be used to measure leaf photosynthesis. During the lab session, students will learn to operate the equipment, and measure leaf photosynthesis under different precipitation treatments, in a field experimental setting. They will also use analysis of variance (ANOVA) to analyze their results, and write a lab report.

Objectives: At the end of this lab exercise students will be able to:

1. Use the Li-6400 to measure leaf photosynthesis
2. Understand how precipitation treatments may influence leaf photosynthesis
3. Use the scientific method appropriately to answer a question, including generating hypotheses, designing an experiment, and statistically analyzing data.
4. Clearly communicate scientific results in writing and in the appropriate format

Equipment/ Logistics Required:

- Li- 6400 Portable Photosynthesis System
- Swichgrass plants grown under different precipitation treatments
- A ruler to measure leaf width

Summary of What is Due:

- A formal, 3 to 5 page Lab Report written by individuals

C. Description of the Lab Activity

Introduction

Photosynthesis is an important biological process by which light energy is converted into chemical energy. Understanding energy conversions is critical, as all organisms need energy to survive and reproduce, and plant photosynthesis provides energy for all other organisms.

Photosynthesis converts light energy into the chemical energy of sugars and other organic compounds. This process consists of a series of chemical reactions that require carbon dioxide (CO_2) and water (H_2O) and store chemical energy in the form of carbohydrate (sugar). Light energy from light drives the reactions. Oxygen (O_2) is a byproduct of photosynthesis and is released into the atmosphere. The following equation summarizes photosynthesis: $6\ CO_2 + 6\ H_2O \rightarrow 6(CH_2O) + 6\ O_2$

Photosynthesis transfers electrons from water to energy-poor CO_2 molecules, forming energy-rich sugar molecules. This electron transfer is an example of an oxidation-reduction process: the water is oxidized (loses electrons) and the CO_2 is reduced (gains electrons). Photosynthesis uses light energy to drive the electrons from water to their more energetic states in the sugar products, thus converting solar energy into chemical energy.

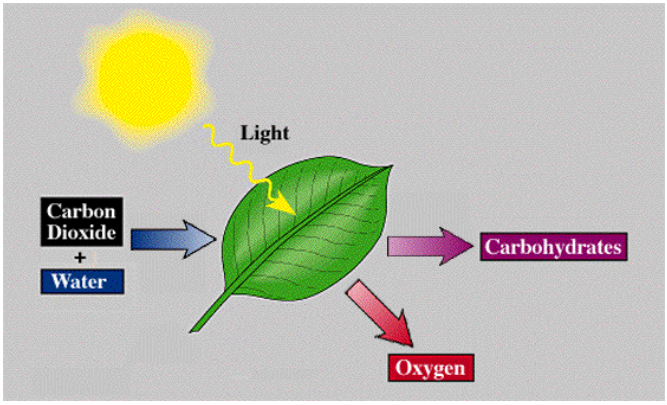

Figure. Overview of photosynthesis (Image from Person, the Biology Place)

Switchgrass (*Panicum virgatum* L.) is a perennial C4 grass widely distributed from southern Canada to the US and Mexico. It is one of the most dominant grass species within the tallgrass prairie ecosystem. The characteristics of switchgrass that make it more attractable than other grass species include the production of high biomass, high nutrient use efficiencies, tolerant of a broad range of environmental conditions, and ability to sequester atmospheric carbon in the soil. For example, Schmer et al. reported that the annual switchgrass biomass averaged 5.2 -11.1 Mg ha-1. Biomass production of switchgrass may be influenced by many factors, such as soil nutrients, varieties, and climatic factors like precipitation.

Research on switchgrass has been conducted over the past decades, particularly on variety comparisons, field management schemes, nutrient limitation responses, and life cycle assessments. Physiological studies have been mostly limited to the study of differences among switchgrass cultivars and different agricultural practices. Different switchgrass varieties show different leaf photosynthetic rates, ranging from 25.4 to 35.4 μmol CO_2 $m^{-2}s^{-1}$. Compared to other crop types, the effects of climate change, such as

water stresses on switchgrass, have not been well investigated. Some studies compared differences in annual precipitation and temperature and found that inter-annual precipitation influences soil water availability and then the physiology of switchgrass. The soil water stress significantly reduced switchgrass aboveground biomass, establishment rates of stands, and physiological responses. But few experimental studies have been conducted to investigate the responses of switchgrass physiology and growth to climate changes.

Precipitation is a very important factor influencing ecosystem productivity and biomass. This lab is designed to determine the effects of sustained precipitation changes on leaf physiology, specifically leaf photosynthesis of switchgrass.

Materials and Methods

Study Site:

The experiment was conducted in an environmentally controlled greenhouse at Tennessee State University Agricultural Research and Demonstration Center (Latitude 36.12'N, Longitude 86.89'W, Elevation 127.6 m) in Nashville, Tennessee.

Seeds of "Alamo" switchgrass were planted in the field in April 2011. PPT facility was constructed in the switchgrass field in March 2015. Five levels of PPT treatments were considered, including -50%, -33%, +0%, +33%, and +50% of ambient precipitation. We used a rainfall-interception-redistribution (RIR) system that combines a modified rainout shelter originally designed by Yahdjian and Sala (2002) with a water redistribution system described by Zhou et al. (2006, 2012).

Overview of Data Collection and Analysis Methods

1. Learn to use the Li-6400 equipment for leaf photosynthesis measurements.
2. Select leaves under different precipitation treatments, and measure maximum leaf photosynthetic rate and transpiration using a Li-6400 Portable Photosynthesis System (Li-Cor Inc., Lincoln, NE). The fully expanded young leaves of five selected tillers in each treatment plot are measured. Leaf chamber photosynthetic photon flux density was set at 2000 µmol m-2s-1.
3. Measure the width of leaf when you do not fill the leaf chamber full, and record each leaf width. These numbers will used for leaf photosynthesis correction after you downloading data from the Li-6400 instrument.
4. Download data and analyze data for the effects of precipitation on leaf photosynthesis.

Homework:

Write a lab report using the proper format. Your Instructor will assign a due date for the lab report.

Questions for Further Thought and Discussion

1. How did your measurements vary if you select leaves of different ages?
2. If you measure leaf photosynthesis at different time, how would temperature influence your leaf photosynthesis measurement? What's the best time for leaf photosynthesis measurement in a day?
3. Will the CO2 concentration change in the field influence leaf photosynthesis measurements?
4. Are there other environmental or site factors that you did not measure that could influence leaf photosynthesis measurements?

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Tools for Assessment of Student Learning Outcomes:

Assessment

Students will be assessed through the written lab report. The lab report will be used to test your comprehension of the principles behind soil respiration and your ability to communicate in writing in proper scientific format.

Experimental Design Guidelines
Lab Report Guidelines

Rubrics

Lab Report Prime Trait Assessment (EXCEL file and WORD file)

Sample Exam Questions

Q. The process that converts atmospheric CO_2 into organic C in plants is_____.
A. *Photosynthesis*

Q. If global warming were to lead to warmer soil temperatures and therefore faster decomposition worldwide, what would you expect to happen to the levels of CO_2 in the atmosphere (all else being equal)? Explain.
A. *Faster decomposition would lead to greater CO_2 emission rates which would lead to an increase in atmospheric CO_2 concentration.*

D. Comments to Faculty Users

Experiment Description

Introducing the Experiment to Your Students
Typically the introductory material (such as leaf photosynthesis) can be covered in lecture before the lab activity, so students are somewhat familiar with it. In lab we begin indoors where the concepts can be reviewed briefly. The operation of the Li-6400 for leaf photosynthesis needs some training, as temperature, light, flow rate should be set to constant before measurements. Students need to understand how the equipment works before starting the measurements. After they learn to use the machine, they can work as groups to design the experiment and collection leaf photosynthesis under different precipitation treatments.

Data Collection and Analysis Methods Used in the Experiment
Time could be an issue for spring semester, as switchgrass is not growing at the time. Some greenhouse plants may be used for experiments. For the fall semester, it is fine to measurement leaf photosynthesis.

Weather is an important consideration. After rain, it is not good for leaf photosynthesis measurements. Excessive moisture as during a rain storm or flooded conditions could influence measurements.

Questions for Further Thought

1. Instructors may need to help students summarize their environmental measurements and to figure out exactly what they mean. For example, students may not immediately grasp the idea that precipitation treatments would influence leaf photosynthesis.
2. Students may choose other studies with this experimental setting. For example, they may investigate age effects of leaf on photosynthesis. They may also investigate the influence of CO2 concentration on leaf photosynthesis (A-ci curve), or the influence light on leaf photosynthesis (A-I curve).

Comments on Formative Evaluation of this Experiment
The formative evaluation is a Quiz/Survey given at the beginning of Lab. It is intended to assess the degree to which they have achieved learning objective and also to identify any problem areas. The quiz portion contains five objective questions to assess content knowledge. The survey portion contains two

questions asking students about 1) anything that is not clear, 2) the hardest part of the activity so far. No grade was associated with the quiz in my courses but an instructor could use it as a graded assignment.

Comments on Translating the Activity to Other Institutional Scales or Locations:
The experiment can be adapted for indoors when the weather does not cooperate. Indoor plants can be used for photosynthesis measurements. The indoor setting would also be more suitable for students with physical disabilities.

The Li-6400 Photosynthesis System can be used in different ecosystems, croplands, grasslands and forests.

E. Appendix

Sample leaf photosynthesis of three species

Elm	Maple	Ilexx
8.343417	2.4561466	23.17569
6.803163	2.789348	25.20185
9.063846	2.534432	24.31487
7.377949	3.010177	24.24126
5.997296	3.1679995	25.94882

Sample ANOVA result

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Elm	5	37.58567	7.517134	1.478524
Maple	5	13.9581	2.791621	0.09203
Ilexx	5	122.8825	24.5765	1.104357

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1313.222	2	656.6111	736.4106	<0.0001	3.885294
Within Groups	10.69965	12	0.891637			
Total	1323.922	14				