Supplement 1: Full Reading Annotation Exercise

Why are you doing this exercise?

This is a **low-stakes diagnostic exercise.** Our research tells us that students tend to make similar mistakes on this diagnostic exercise and on their formal lab reports. In other words, what you get wrong on this annotation homework **predicts what you are more likely to do incorrectly** on a lab report.

You will be able to download your answers at the end of the activity. If you pay extra attention as you write to areas where you made mistakes in this low-stakes exercise, you are less likely to lose points on the higher-value formal lab report.

This is not a points-based quiz!

You will earn full credit if you **try your best** to complete the assignment and **learn** from any mistakes you make.

What will you be doing?

You will be highlighting and marking up text using different colored tags. The colors make it easier to understand the markup when you print out your results at the end. There are some multiple-choice questions too, like what you see on pre-lab quizzes.

You can do the in-class practice portion without doing any background reading. You need read the section of the *BioCore Resource Guide* on writing lab reports (pp. 41-52 in Ver. 19.2) before doing the homework part of this exercise.

How your TA will use the results

Your TA will get a report summarizing responses from you and your lab mates. They will use your highlights and questions to fine-tune next week's discussion about scientific writing and how to organize your lab report.

Some Terms You Need to Know

These are important features of scientific writing that many past students struggled with when they first started out. We pointing them out now to help you learn to avoid them. As you gain experience, you will develop you own sense of what is appropriate in scientific communication. Other terms like hypothesis, independent and dependent variable, controls, etc., are defined and discussed in detail in the *BioCore Resource Guide*.

Scientific vs. Non-Scientific Language

A **scientific term** is a word or phrase that has a precise or formal definition specific to science or biology specifically. Someone who has not studied college-level science is unlikely to know the meaning.

A **colloquial term** is a word or phrase that is informal or less precise. You also can think of it as an "unscientific term." You would be likely to use the word or term in casual conversation, or see it in poetry or a novel, but NOT in formal scientific writing.

There is no clear-cut rule that separates scientific versus colloquial terms. The best way to learn what is appropriate wording in scientific writing is to READ scientific literature.

Scientific vs. Common Knowledge

A **biological statement** is a sentence or phrase stating a previously established biological fact or an observation or experimental result. Usually these are not common knowledge, and so you will need to cite the source for the information.

A **common knowledge statement** is a sentence or phrase stating a well-known fact or piece of information in the scientific community. It may not be well-known by non-scientists, but someone who has some basic scientific knowledge probably does not need to know the specific source of that information.

Like scientific vs. colloquial terms, there are no clear-cut rules saying what statements are common knowledge versus biological statements. You will develop a better idea of what needs a citation as you read more literature. In general it is better to provide more citations than needed than to provide too few citations. There is no penalty for excess citations, but NOT citing some fact that should be is a form of plagiarism.

Research Question vs. Hypothesis

A **research question** is RELATED to a **hypothesis**, but they are not identical. Usually a **hypothesis** is formatted as an "If ... /Then ... statement." Each hypothesis tries to predict a single outcome (the "Then" part) based on specific starting conditions & assumptions (the "If" part of the statement.) Some primary literature may not have an obvious "if/then" hypothesis statement. The authors of these articles leave it to readers to work out their hypothesis. This is not a good practice generally, and we want you to always include a clear hypothesis statement in your reports for now.

A **research question** is a **broader** statement of an author's specific aim or purpose for performing a series of experiments, or the overall question they hope to answer by collecting a particular set of observations then analyzing them. Often the research question is near the end of the Introduction section. It is very rare for a primary article not to have a statement of the main research question(s) for that article. In your reports, the research question usually will be just before your hypothesis statement.

In-Class Exercise

The text for Sample #1 below is split into **two paragraphs**, but they belong together. To mark up text, **click and drag to highlight one or more words.** Then click on one of the displayed labels to color and tag the highlighted text. If you make a mistake, simply highlight the mistake and click "Remove" from the label options shown.

When you annotate, mark the longer phrases or sentences first. Then go back and mark the shorter phrases or individual words. *If you do not see an example of any of the items listed, simply leave that annotation tag unused*

In-Class Practice Sample #1

For this practice example, you have 3 options for labeling text.

1. *First, look for and tag **3 biological statements** (statements about an established biological fact or result that need to be supported with evidence).*
2. *Next, mark all **scientific terms** that you think a person without college-level biology would not know.*
3. *Finally, mark any **colloquial terms** you think are not appropriate for a scientific article.*

Biological statement | Scientific term | Colloquial term

Nosemosis, or Nosema disease, is caused by two species of microsporidian parasites (a type of spore forming fungus) called Nosema apis and Nosema ceranae. N. apis is thought to have originated on European honey bees, while N. ceranae is thought to have evolved as a pest of Asian honey bees (Apis cerana) and has only started to affect the European honey bees relatively recently. N. ceranae appears to be more damaging than N. apis, affecting more cells in the bees mid-gut and killing infected bees faster than N. apis.

Biological statement | Scientific term | Colloquial term

Infection of adult bees at a young age can cause the bee to have difficulty digesting food for the rest of its life. These bees usually do not produce brood food/royal jelly secretions from the hypopharyngeal glands and often skip the brood rearing stage of their life, becoming forager bees at a young age. The infected bee often has a shortened adult lifespan. When queen bees become infected they also have reduced lifespans and cease to lay eggs. These impacts cause reduced colony health, population and performance, which can ultimately result in the colony dying.

Based on the wording of this example, for what audience was the text written?

- Scientific Community
- General (Lay) Public

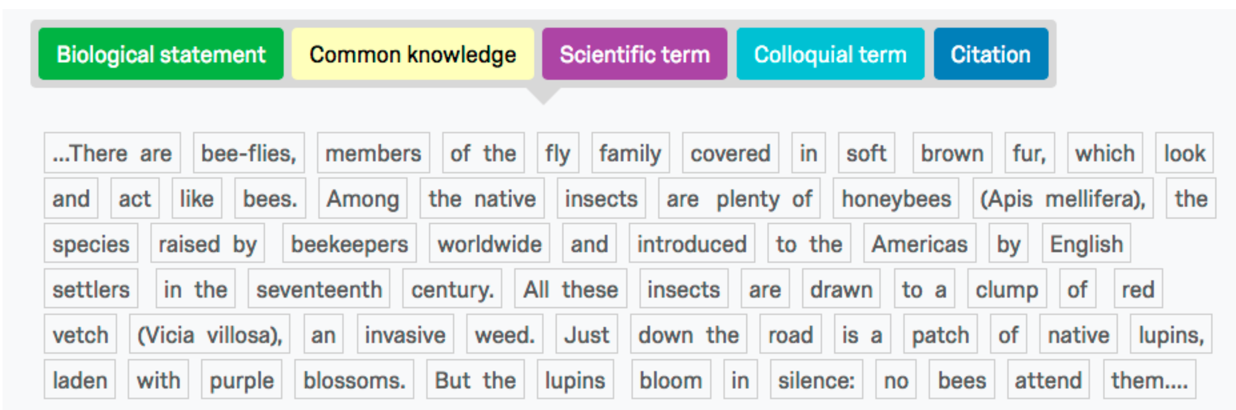
Does this text read like it is part of a scientific paper?

- Yes
- No
- I don't know

In-Class Practice Sample #2

This time the annotation is a bit harder. Remember, *mark larger blocks of text first, THEN go back and mark the individual items or terms.*

1. *First, look for and label 2 biological statements that need support of evidence.*
2. *Next, label any common knowledge statements.*
3. *Next, label all of the scientific terms you can find.*
4. *Next, mark all colloquial terms you think do not belong in a scientific paper.*
5. *Finally, label all citations you can find.*



Based on the wording of this example, for what audience was the text written?

- Scientific Community
- General (Lay) Public

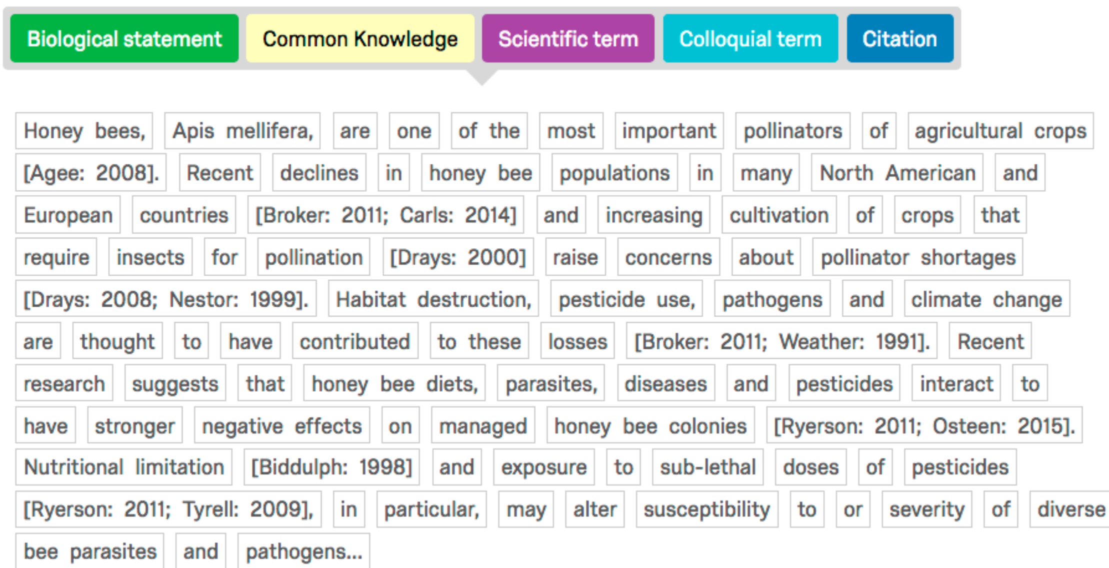
Does this text read like it is part of a scientific paper?

- Yes
- No
- I don't know

In-Class Practice Sample #3

Annotate the text below by clicking on the words and choosing from the given labels. *Mark longer terms and phrases first and then mark individual terms.*

1. *First, look for and label **2 biological statements** that need support of evidence.*
2. *Next, label any **common knowledge statements** (if present).*
3. *Next, label **2-3 scientific terms**.*
4. *Next, mark **all colloquial terms** you think **do not** belong in a scientific paper.*
5. *Finally, label **2 citations**.*



Based on the wording of this example, for what audience was the text written?

- Scientific Community
- General (Lay) Public

Does this text read like it is part of a scientific paper?

- Yes
- No
- I don't know

Homework

The rest of this annotation exercise is your homework assignment. The assignment takes about 1 hour to complete. Remember, read pp. 41-52 of the Resource Guide *first.*

There are 7 ***blocks.*** *Each block focuses on a different part of a primary literature article. Your answers to questions in each block help us understand how well you understand what we expect you to write in your own lab reports, and what may be unclear.*

*You need to complete this at l**east 1 day before your next lab meeting**. Your GTA will get a report of how the class responded, and use it to guide a class discussion of confusing or unclear points.*

Block 1

Annotate the text below by clicking on phrases or words and choosing from the given labels. Mark whole sentences first and then mark individual terms.The text is split up in ***2 paragraphs****. Treat both paragraphs as one, and:*

1. *Find and label the* ***research goals*** *or* ***hypothesis****.*
2. *Label* ***2 citations****.*

Research question | Hypothesis | Citation

Honey bees, Apis mellifera, are one of the most important pollinators of agricultural crops [Ayers: 2008]. Recent declines in honey bee populations in many North American and European countries [Lays: 2013; Prignell: 2015] and increasing cultivation of crops that require insects for pollination [Schneider: 1998] raise concerns about pollinator shortages [Acros: 2018]. Habitat destruction, pesticide use, pathogens and climate change are thought to have contributed to these losses [Lays: 2008; Inselm: 2001; Burris: 2000]. Recent research suggests that honey bee diets, parasites, diseases and pesticides interact to have stronger negative effects on managed honey bee colonies [Delft: 1998; Natros: 1996]. Nutritional limitation [Natros: 1998; Curris: 1997] and exposure to sub-lethal doses of pesticides [E.Johnson, 2001; Engrowd, 2007], in particular, may alter susceptibility to or severity of diverse bee parasites and pathogens...

Research question | Hypothesis | Citation

...This study addresses two important questions. 1) What types of pesticides might bees be exposed to in major crops? While multiple studies have characterized the pesticide profile of various materials inside a honey bee nest [Ostrello, 1997; Balinga, 1997], few have looked at the pollen being brought back to the nest. 2) How do field-relevant pesticides blends affect bees' susceptibility to infection by the Nosema parasite?...

Given the structure, where does this text belong in a scientific paper?

- Introduction
- Abstract
- Materials and Methods
- Results
- Discussion

If response to previous question = Introduction, display this:

Which of the following statements are true about the INTRODUCTION part of a scientific paper?

	No	I don't know	Yes
Contains biological statements.	O	O	O
Has citations.	O	O	O
Shows reproducibility of the experiment.	O	O	O
Objectively states outcomes.	O	O	O
Is a summary of the paper.	O	O	O
Is written in past tense.	O	O	O
Contains hypothesis or research goals.	O	O	O
Explains why study is relevant.	O	O	O
Subjectively interprets the findings.	O	O	O

Do you have any questions about writing this part of a report?

Block 2

Annotate the text below by clicking on phrases or words and choosing from the given labels. Mark whole sentences first and then mark individual terms. The text is split up in 2 blocks. Treat both blocks as one, and:

1. *Look and label all* ***statistical analyses or procedures****.*
2. *Identify the* ***control and independent variable*** *in the experiment.*

Statistics | Independent variable | Control

...To look for potential effects of individual pesticides on susceptibility to Nosema infection, we calculated the relative risk and its 95% confidence interval for bees becoming infected after consuming pollen with a specific pesticide. Relative risk measures the chance of developing a disease after a particular exposure [Etron-Hall, 1997], here each pesticide. A relative risk value of one indicates that the probability of infection is equal between exposed and non-exposed groups.

We further tested effects of pesticides in pollen on measured Nosema prevalence using a generalized linear mixed model with a bee's Nosema status as the response variable, the source hive and pesticide variables as fixed effects, and the pollen sample fed to the bee as a random effect. Collinearity prevented developing a full model to investigate in detail how pesticides and pollen source affect bees' susceptibility to Nosema infection. We thus selected for analysis two measures that vary with crop and are not nested: total pesticide diversity and fungal load. To graph logistic regression results in a meaningful manner, we followed recent recommendations [Omeah, 2005; Omeah 2009] and a modification of the logi.hist.plot function in the R popbio package [Edgemont, 2018] that shows our mixed model output...

Statistics | Independent variable | Control

...The Nosema infection experiment is similar to published methods [Balinga, 2009]. We obtained 210 disease-free honey bees from each of three healthy colonies at the Bee Research Laboratory. Each bee was placed into one of 21 groups upon emergence, with the ten bees in the same group and from the same colony housed together in a wooden hoarding cage (12×12×12 cm). Each group of bees was fed 1 g of pollen mixed with 0.5 mL of syrup (1:1 sucrose to water by weight), which they fully consumed in 2–4 days. These pollen cakes were placed in small petri dishes with the laboratory cages. Pollen from either one of the crop fields or one of two control diets were used. The pollen control group ("BRL") was fed a mixed pollen diet prepared by the USDA-ARS Bee Research Laboratory. This pollen was collected in the desert Southwest (Arizona Bee Products, Tucson, AZ) and tested as pesticide-free by the USDA Agricultural Marketing Service prior to use. A protein control group was fed an artificial honey bee pollen substitute, MegaBee®...

Given the structure, where does this text belong in a scientific paper?

- Introduction
- Abstract
- Materials and Methods
- Results
- Discussion

If response to previous question = Materials and Methods, display this:

Which of the following statements are true about the MATERIALS AND METHODS part of a scientific paper?

	No	I don't know	Yes
Contains biological statements.	O	O	O
Has citations.	O	O	O
Shows reproducibility of the experiment.	O	O	O
Objectively states outcomes.	O	O	O
Is a summary of the paper.	O	O	O
Is written in past tense.	O	O	O
Contains hypothesis or research goals.	O	O	O
Explains why study is relevant.	O	O	O
Subjectively interprets the findings.	O	O	O

Do you have any questions about writing this part of a report?

Block 3¶ *Annotate the text below by clicking on the words and choosing from the given labels.* *<u>Mark whole sentences first and then mark individual terms</u>.*

1. *Label **all statements relating to reporting statistical results** you can find.*

Statistics

...Bee colonies collected different amounts of pollen in the different crops (Table 1; Kruskal-Wallis test: H7 =29.6, p= 0.0001). Pollen diversity, estimated by quantifying the number of differently colored pollen pellets collected in pollen traps, varied by crop (Table 1; Kruskal-Wallis test: H7 =23.5, p= 0.0014). The proportion of pollen that bees collected from the target crop, except for almond and apple, was low (mean= 0.3360.05; Table 1). Like pollen weights, this proportion dramatically differed between crops (Fig. 1; H7 = 44.86, p,0.0001). Notably, none of the pollen trapped from hives in blueberry, cranberry (early and late), pumpkin or watermelon fields was from the target crop...

Given the structure, where does this text belong in a scientific paper?

- Introduction
- Abstract
- Materials and Methods
- Results
- Discussion

If response to previous question = Results, display this:

Which of the following statements are true about the RESULTS part of a scientific paper?

	No	I don't know	Yes
Contains biological statements.	O	O	O
Has citations.	O	O	O
Shows reproducibility of the experiment.	O	O	O
Objectively states outcomes.	O	O	O
Is a summary of the paper.	O	O	O
Is written in past tense.	O	O	O
Contains hypothesis or research goals.	O	O	O
Explains why study is relevant.	O	O	O
Subjectively interprets the findings.	O	O	O

Do you have any questions about writing this part of a report?

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Block 4

*Annotate the text below by clicking on the words and choosing from the given labels. <u>Mark whole sentences first and then mark individual terms</u>. The text is split up into **2 paragraphs**. Treat both paragraphs as one, and:*

1. *Label **ALL** sentences that contain **interpretations of evidence or data**.*

Interpretation

...The results from this study highlight several patterns that merit further attention. First, despite being rented to pollinate specific crops, honey bees did not always return to the nest with corbicular pollen from those crops. These findings support other research with honey bees and native bees indicating that in some crops native bees may be more efficient pollinators [Endrila, 2003]. Second, fungicides were present at high levels in both crop and non-crop pollen collected by bees. Third, two fungicides (chlorothalonil and pyraclostrobin), and two miticides used by beekeepers to control varroa infestation (amitraz and fluvalinate) had a pronounced effect on bees' ability to withstand parasite infection. Research on pesticides' effects on bee health has focused almost exclusively on insecticides (e.g. fipronil [Ryerson, 2001] and the neonicotinoids imidacloprid and thiacloprid [Emilson, 2001; Nettles, 2009; Eccles, 2004]). Finally, several individual pollen samples contained loads higher than the median lethal dose for a specific pesticide. While multiple studies have shown negative effects of specific pesticides on honey bee individual and colony health [Endrila, 2003; Opales, 2004; Styles, 2017] and high pesticide exposure [Styles, 2016; Endicott, 2016], ours is the first to demonstrate how real world pollen-pesticide blends affect honey bee health...

Interpretation

...Our results show that beekeepers need to consider not only pesticide regimens of the fields in which they are placing their bees, but also spray programs near those fields that may contribute to pesticide drift onto weeds. The bees in our study collected pollen from diverse sources, often failing to collect any pollen from the target crop (Fig. 1). All of the non-target pollen that we were able to identify to genus or species was from wildflowers (Table 1), suggesting the honey bees were collecting significant amounts of pollen from weeds surrounding our focal fields. The two exceptions to this were hives placed in almond and apple orchards. Almond flowers early in the year, and almond orchards are large, thus providing honey bees with little access to other flowers. Honey bees rarely collect pollen from blueberry or cranberry flowers, which only release large quantities of pollen after being vibrated by visiting bees (buzz pollination) [Wyerly, 2009; Estella, 2015]. Honey bees are not capable of buzz pollination and thus are unlikely to collect large amounts of pollen from these plants to bring back to the colony. Bumble bees, which can buzz pollinate, collect mainly blueberry pollen when placed in blueberry fields [Myers, 2001]. Interestingly, the two crops that saw high levels of pollen collection by honey bees are Old World crops that evolved with honey bees as natural pollinators. Crops native to the New World, where honey bees have been introduced, yielded little or no pollen in our samples...

Given the structure, where does this text belong in a scientific paper?

- o Introduction
- o Abstract
- o Materials and Methods
- o Results
- o Discussion

If response to previous question = Discussion, display this:
Which of the following statements are true about the DISCUSSION part of a scientific paper?

	No	I don’t know	Yes
Contains biological statements.	O	O	O
Has citations.	O	O	O
Shows reproducibility of the experiment.	O	O	O
Objectively states outcomes.	O	O	O
Is a summary of the paper.	O	O	O
Is written in past tense.	O	O	O
Contains hypothesis or research goals.	O	O	O
Explains why study is relevant.	O	O	O
Subjectively interprets the findings.	O	O	O

Do you have any questions about writing this part of a report?

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Block 5

Go through these selected citations from the Literature Cited section and annotate the text according to the labels.

Authors | Title | Year | Publisher | Pages

1. Klein A-M, Vaissiere BE, Cane JH, Steffan-Dewenter I, Cunningham SA, et al. (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B-Biological Sciences 274: 303–313.

2. Biesmeijer JC, Roberts SPM, Reemer M, Ohlemuller R, Edwards M, et al. (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science 313: 351–354.

Citation formats vary from journal to journal, and course to course. In BioCore we use a modified version of Harvard's *Name-Year* format. It is described in detail in the *Resource Guide*.

Suppose you wanted to use the two references in the previous question in your lab report. Based on the format in the *Resource Guide*, which of the choices below is the correct one?

- ...[1]...[2]...
- ...[Klein et al., 2007]...[Biesmeijer et al., 2006]...
- ...[Klein: 2007]...[Biesmeier: 2006]...
- ...(Klein et al. 2007)...(Biesmeijer et al. 2006)...
- ...(Klein)...(Biesmeijer)...

Do you have any questions or comments about citations you want the TA to discuss or clarify?

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Block 6

Annotate the text below by clicking on the words and choosing from the given labels. Hint: some of them may not be present. Mark whole sentences first and then mark individual terms.

1. *Label* ***2 biological statements****.*
2. *Label the main* ***research goals****.*
3. *Label* ***statistical tests or results****.*
4. *Label the* ***citations****.*

Citation | Biological statement | Research question | Statistics

Recent declines in honey bee populations and increasing demand for insect-pollinated crops raise concerns about pollinator shortages. Pesticide exposure and pathogens may interact to have strong negative effects on managed honey bee colonies. Such findings are of great concern given the large numbers and high levels of pesticides found in honey bee colonies. Thus it is crucial to determine how field-relevant combinations and loads of pesticides affect bee health. We collected pollen from bee hives in seven major crops to determine 1) what types of pesticides bees are exposed to when rented for pollination of various crops and 2) how field-relevant pesticide blends affect bees' susceptibility to the gut parasite Nosema ceranae. Our samples represent pollen collected by foragers for use by the colony, and do not necessarily indicate foragers' roles as pollinators. In blueberry, cranberry, cucumber, pumpkin and watermelon bees collected pollen almost exclusively from weeds and wildflowers during our sampling. Thus more attention must be paid to how honey bees are exposed to pesticides outside of the field in which they are placed. We detected 35 different pesticides in the sampled pollen, and found high fungicide loads. The insecticides esfenvalerate and phosmet were at a concentration higher than their median lethal dose in at least one pollen sample. While fungicides are typically seen as fairly safe for honey bees, we found an increased probability of Nosema infection in bees that consumed pollen with a higher fungicide load. Our results highlight a need for research on sub-lethal effects of fungicides and other chemicals that bees placed in an agricultural setting are exposed to.

Given the structure, where does this text belong in a scientific paper?

- ○ Introduction
- ○ Abstract
- ○ Materials and Methods
- ○ Results
- ○ Discussion

If response to previous question = Abstract, display this:
Which of the following statements are true about the ABSTRACT part of a scientific paper?

	No	I don't know	Yes
Contains biological statements.	O	O	O
Has citations.	O	O	O
Shows reproducibility of the experiment.	O	O	O
Objectively states outcomes.	O	O	O
Is a summary of the paper.	O	O	O
Is written in past tense.	O	O	O
Contains hypothesis or research goals.	O	O	O
Explains why study is relevant.	O	O	O
Subjectively interprets the findings.	O	O	O

Do you have any questions about writing this part of a report?

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Block 7

Based on the abstract reprinted below, write a title for the paper.

HINT: a title normally contains the name of the study organism and main outcome of the paper. The *Resource Guide* has additional information about what goes in good titles.

Abstract:

> "Recent declines in honey bee populations and increasing demand for insect-pollinated crops raise concerns about pollinator shortages. Pesticide exposure and pathogens may interact to have strong negative effects on managed honey bee colonies. Such findings are of great concern given the large numbers and high levels of pesticides found in honey bee colonies. Thus it is crucial to determine how field-relevant combinations and loads of pesticides affect bee health. We collected pollen from bee hives in seven major crops to determine 1) what types of pesticides bees are exposed to when rented for pollination of various crops and 2) how field-relevant pesticide blends affect bees' susceptibility to the gut parasite Nosema ceranae. Our samples represent pollen collected by foragers for use by the colony, and do not necessarily indicate foragers' roles as pollinators. In blueberry, cranberry, cucumber, pumpkin and watermelon bees collected pollen almost exclusively from weeds and wildflowers during our sampling. Thus more attention must be paid to how honey bees are exposed to pesticides outside of the field in which they are placed. We detected 35 different pesticides in the sampled pollen, and found high fungicide loads. The insecticides esfenvalerate and phosmet were at a concentration higher than their median lethal dose in at least one pollen sample. While fungicides are typically seen as fairly safe for honey bees, we found an increased probability of Nosema infection in bees that consumed pollen with a higher fungicide load. Our results highlight a need for research on sub-lethal effects of fungicides and other chemicals that bees placed in an agricultural setting are exposed to."

Your Title:

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Do you have any questions or comments about titles you want the TA to discuss or clarify?

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Congratulations! You've finished the assignment!

Please re-enter your **email address** so your TA knows you completed the exercise.

____

When you submit your answers, you will see a button or link that lets you download a PDF copy of your assignment.

MAKE SURE you download a personal copy. You need it for your next lab meeting, and we cannot pull your individual responses out very easily if you forget.

Sources
Text in this exercise was taken from:

1. http://beeaware.org.au/archive-pest/nosema
2. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0070182

Supplement 2: Example Lab Reports

SAMPLE REPORT 1

Date submitted: 2018-10-01 12:12:18
ID: R_3gklfFTZDDajEA7
Course number: 103
TA: TA0000304

The Effect of Herbivory on Energy Allocation of Field Peas

Abstract

Resource allocation consists of plants deciding where energy should be used in their systems. This is in an effort to increase fitness and survive in an environment where these resources are limited. Plants are able to respond to their environment and change their allocation patterns in order to become more fit. In this lab we sought information on how herbivory, the consumption of plants by animals, impacted how Field Peas allocated resources between its roots and its shoots. We simulated herbivory by removing leaves and measures energy allocation by recording root:shoot ratios for mass and length. Our results indicate that herbivory has no impact on plant energy allocation. This proves to be in conflict with findings of other published studies. We believe that there were key limitations to our study that yielded these differing results and that further experimentation with methodical modification would produce results that showed the proper impact that herbivory has an energy allocation. This knowledge would be important in an agricultural context and could help farmers maximize crop yield.

Introduction

The concept of limited resources is the driving idea behind evolutionary and ecological study. How organisms battle for these resources and use them, determines many factors about them such as their location, structure, shape, and many more. One key aspect of how an organism interacts with and uses resources is energy allocation. Energy allocation is the way an organism uses its energy. For example, whether plants use more resources for root growth or for shoot growth demonstrates how a plant could allocate its energy. Organisms are generally designed to have certain energy allocation protocols, but there is a certain degree of plasticity associated with the matter. Organisms are able to adapt to a particular environment or environmental change by altering how it allocates its resources. This is all in an effort to increase fitness and survival rate in a world of limited resources [Lerdau: 1997]. In this laboratory, we explored how herbivory impacted Field Pea (Pisum sativum) energy allocation by recording root to shoot ratios. The model organism Pisum sativum was used due to its short growth cycle, ease of maintenance in a green house, and compatibility with US southeast fall climate. Herbivory is the act of herbivores damaging plant tissue, via eating, and therefore removing parts of the plants, such as leaves, that are important in energy harvesting [Belsky: 1986]. This issue is prevalent in agricultural settings and could provide insight to agrarian companies and peoples looking for methods to provide optimum plant growth. Field Peas specifically, are extremely valuble to the agriculture of one of the largest nations in the world, India. [Singh: 2016]. Energy allocation affects how a plant grows which also affects its usefulness to humans. We predicted that if field peas were exposed to conditions that resembled herbivory, then the plant would allocate more energy to the shoots and that root: shoot ratio would decrease relative to the control.

Materials and Methods

The first part of the experiment consisted of planting the field peas. The seeds were soaked in water for 30 minutes before planting. While the seeds were soaking, we designated four pots to be the control group and four pots to be the experimental group. All eight pots were filled to the top with vermiculite, pre-watered, and given 50 mL of miracle grow. In each pot we made nine equally spaced intentions about 2-3 times the size of the seeds, and in each indention placed three seeds. After gently covering the seeds, we placed all eight pots in the green house. All pots were soaked fully with water once a day for a week. After one week, the herbivory simulation was performed on the four experimental pots. For each plant that was growing in the experimental pots, half of the leaves were removed. Each pot was subsequently soaked with water daily for one more week before data collection took place. To collect data, we randomly selected five plants from the control and five plants from the experimental group. For each plant, we measured total mass, root mass, shoot mass, and calculated root:shoot ratios. We also measures root length, shoot length, and calculated root:shoot ratios for each plant. Average mass root:shoot ratios and standard deviations were subsequently calculated for the experimental group and the control. Additionally, average length root:shoot ratios and standard deviations were calculated for the experimental group and the control. The mass root:shoot ratios of the two groups were compared using a two tailed t-test, and the length roots:shoot ratios of the two groups were compared using a two-tailed t-test.

Results

Figure 1 compares the root:shoot mass ratios and indicates that the average root:shoot ratio of the experimental group, 0.80±0.10, is not significantly different from the average root:shoot ratio of the control group, 0.71±0.20 ($P>0.05$). Figure 2 compares the root:shoot length ratios and indicates that the average root:shoot ratio of the experimental group, 0.66±0.07, is not significantly different from the average root:shoot ratio of the control group, 0.63±0.08 ($P>0.05$).

Discussion

The results of the experiment do not support our original hypothesis that herbivory decreases root:shoot ratios. The data indicates that there is no relationship between herbivory and how Field Peas allocate energy between their roots and their shoots. This is significant in an agricultural context because it implies that farmers need not concern themselves with animals and insects eating parts of their crops. It further suggests that herbivory does not impact the fitness of the plant as the plant made no effort to adapt to the change. This conclusion is not supported by published studies and we believe several key limitations gave way to our divergent results. One study investigating the impact of insecticides found that decreasing insect herbivory increased plant height and overall size and concluded that herbivory has a considerable effect on plants [Wilbur: 2013]. This contrasts our data as it shows plants do not exist without response to herbivory. Another study states that in response to attack from herbivorious insects, plants typically move carbohydrates and recourses to the roots in an effort to minimize nutrient loss. [Schultz: 2013]. This means that root to shoot ratio would increase, which is contradictory to our findings. It is apparent that herbivory should have an impact on energy allocation and thusly should have impacted our root:shoot ratios. Further experimentation that addresses the limitations of the study should be carried out. We believe that it is possible that one week was not long enough for the effects of the herbivory to be seen and that the herbivory was not intense enough to elicit the appropriate response. We were limited by time and a fear that too much leave removal would prove fatal to our peas. A study carried out over a month with over 75% leaf removal every week would have been an ideal experimental environment. With these experimental changes we believe that a relationship between herbivory and plant resources allocation will be apparent. After this data is procured, the findings would confirm the large impact herbivory has on allocation and therefore plant fitness. Limiting herbivory in plants has been shown to greatly increase fitness [Wilbur: 2016] and more data and information to how this process occurs could prove valuable in increasing crop yields.

Literature Cited

1. Lerdau, Manuel, and Jonathon Gershenzon. "Allocation Theory and." Plant resource allocation (1997): 265.
2. Belsky, A. J. "Does herbivory benefit plants? A review of the evidence." The American Naturalist 127.6 (1986): 870-892.
3. Schultz, Jack C., et al. "Flexible resource allocation during plant defense responses." Frontiers in plant science 4 (2013): 324.
4. Hufbauer, Ruth, et al. "The effect of insect herbivory on the growth and fitness of introduced Verbascum thapsus L." Neobiota 19 (2013): 21.
5. Singh, Sandeep Kumar, et al. "Estimation of correlation coefficient among yield and attributing traits of field pea (Pisum sativum L.)." Legume Research 41.1 (2018): 20-26.

Figure: 1

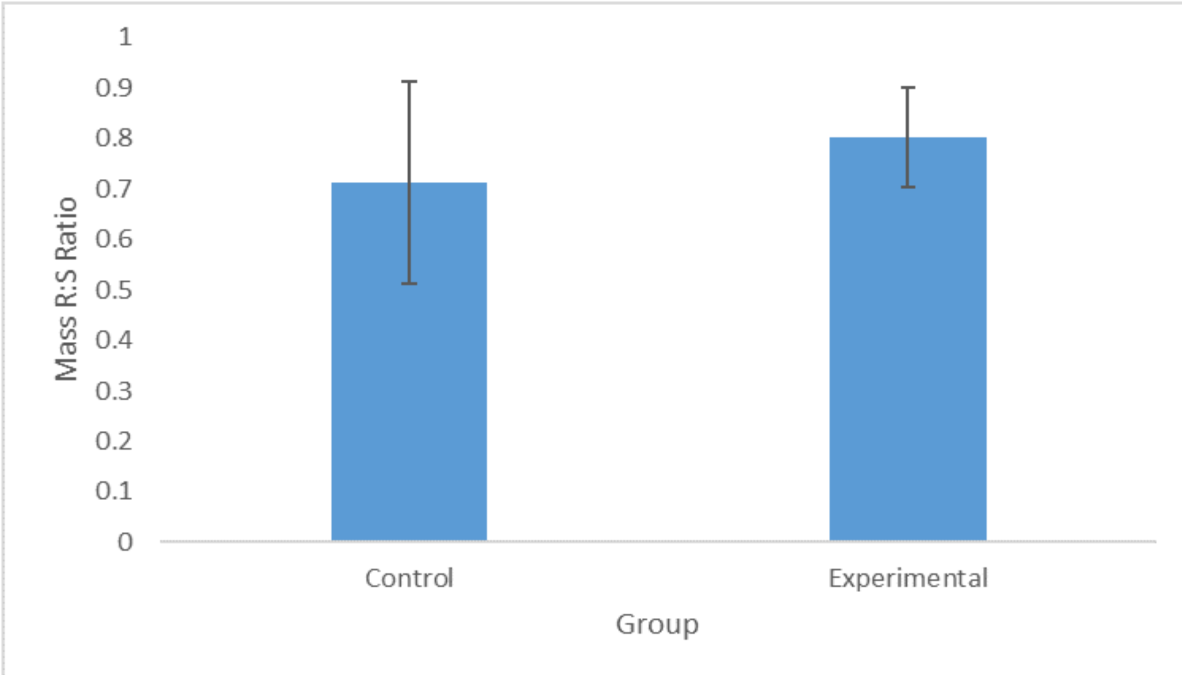
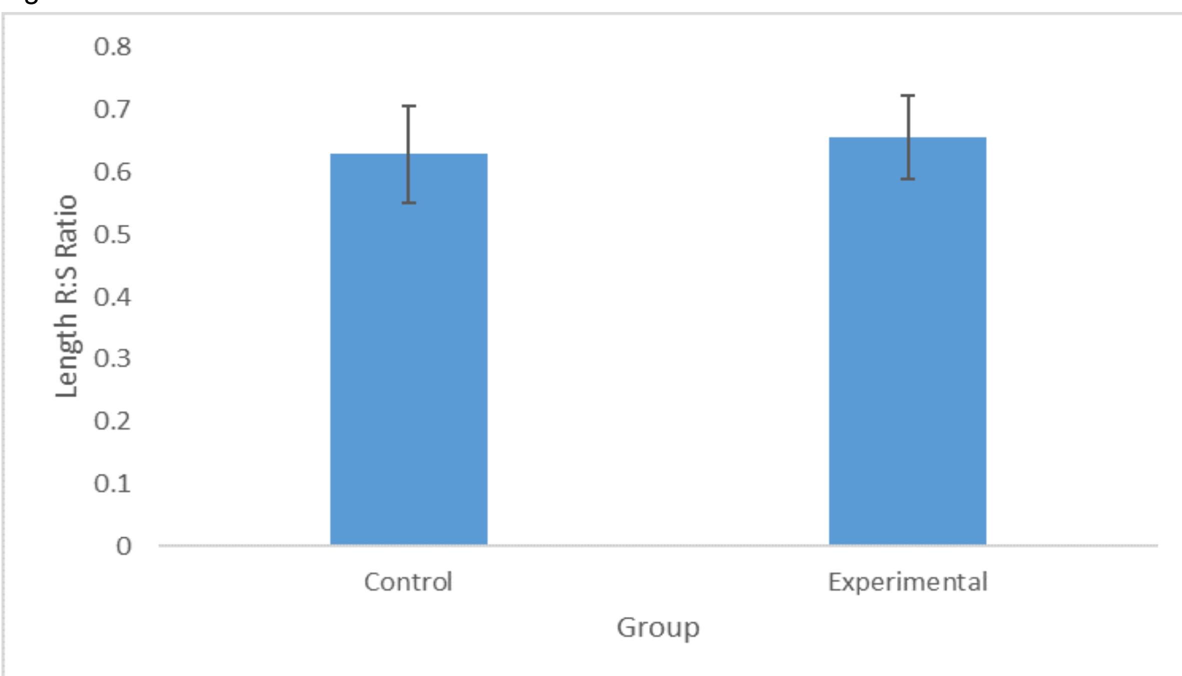


Figure: 2



<u>Figure Legends</u>

Figure 1. A comparison of average mass root:shoot ratios for the control and experimental groups. Figure 2. A comparison of average length root:shoot ratios for the control and experimental groups.

SAMPLE REPORT 2

Date submitted: 2018-10-01 07:10:44
ID: R_2AkJShlNazuVxtv
Course number: 103
TA: TA0000304

Resource and Energy Allocation in Vigna radiata

Abstract

Vigna radiata is a plant which allocated resources to roots or shoots depending on the environment in which it is placed. This experiment looks at this particular plant's ability to allocate resources when placed in normal sun exposure as well as in a shaded area. We placed plants in both normal sunlight exposure and under a shade, then measured root:shoot ratios after the plants grew. In this experiment we found that those plants exposed to less light had a larger root:shoot ratio, as we expected them to.

Introduction

A vital aspect of a plant's life is uptake and allocation of resources. When certain abiotic factors in a plant's environment are changed, the plant also changes its physical form in order to gain appropriate amounts of nutrients and continue to live. This is called Resource Allocation; Resource Allocation happens on the phenotypic level when a plant must make a change in order to be more fit for the environment in which it lives. Such patterns of allocation "play a pivotal role in life history evolution and functional plant ecology" [Bazzaz: 1997]. Plants being exposed to various amounts of light will cause variation in the ways they allocate resources in order to be most fit for their environments. Vigna radiata was an appropriate model organism for this experiment because it is a relatively quickly adapting plant, which allowed easy viewing of its ability to allocate resources. Since the shoot is the part of the plant responsible for photosynthetic processes and a larger root:shoot ratio in a darker area will allow the plant to survive as well as those in areas with greater amounts of sunlight, those plants exposed to less light will allocate more energy for shoot length than those exposed to more light.

Materials and Methods

For this experiment we first soaked 50-60 seeds from the model organism in water prior to planting them. We then placed the seeds in pre-soaked vermiculite with 50mg of "Miracle Gro" in each individual seed hole (six bins of about 6-10 seeds in each bin). We placed three bins on one tray of plants in a greenhouse with natural light exposure, and three under a shade cover with much less light exposure. We watered the plants daily for two weeks, and after they grew appropriately we began to measure the root:shoot ratios. We gathered ten plants from the natural light group and ten from the shaded group. We first weighed the plants respectively, then separated the roots from the shoot (precision and consistency is crucial here for the integrity of the experiment). We then weighed the roots and the shoots of each respective group and calculated weight ratios, after this we measured the length of root and shoot and calculated that ratio as well. Last, measure the maximum root and shoot lengths of each group and record the mean values for both of the plant groups.

Results

The results of this experiment showed a significant difference for weight (t= 13.378, df=4, p= 0.000181) as well as height (t= 3.983, df=4, p=0.016353) with an alpha level of 0.05. The graphs show the differences in both ratios of root:shoot weight and length in the light and dark areas. To calculate significance we used a two-sample t-test and an alpha level of 0.05.

Discussion

Our results supported our hypothesis, as the p-values for both the height and weight ratios were less than the alpha level of 0.05. These data show that the plants which were exposed to less light allocate more energy and resources to shoot length and growth in order to maximize photosynthetic ability. From this experiment we can conclude that plants in generally darker areas will tend to allocate more resources towards shoot growth, which could mean less energy for appropriate root growth. This adaptation can be beneficial for plants needing to increase surface area for photosynthesis, but it could also be dangerous in that less resources will be allocated toward root growth which is also a key factor in a plant's survival and vitality. Knowledge regarding the adaptability of plants can allow researchers to understand exactly how a specific plant will survive in certain, varying environments. This can be essential and helpful in agricultural farming, as we are now able to show which environment a plant will thrive in and have the optimized crop yield. Since plants change so rapidly phenotypically, technologies such as underground x-rays are being created in order to gain a better understanding of plant structure and architecture. Such techniques will "provide a better understanding of how overall plant architecture is regulated...and how best precision agriculture can be exploited to optimize plant growth and seed/fruit development" [Bennett, 2012]. By understanding resource allocation, we can grow crops in highly conducive areas and soils in order to generate the highest possible crop yield. In the future this experiment could be done with varying levels of light exposure (rather than just two) in order to better understand the levels of allocation.

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2.Emma Bennett, Jeremy A. Roberts and Carol Wagstaff. 2012. Manipulating resource allocation in plants. Journal of Experimental Botany. 63: 3391-3400.

Figure: 1

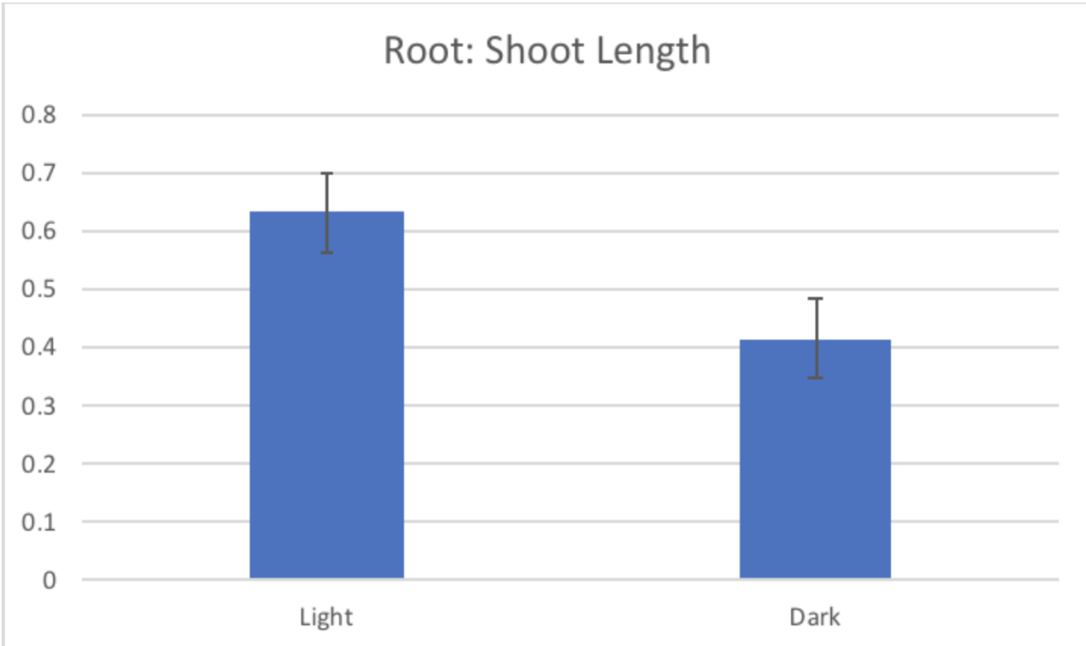


Figure: 2

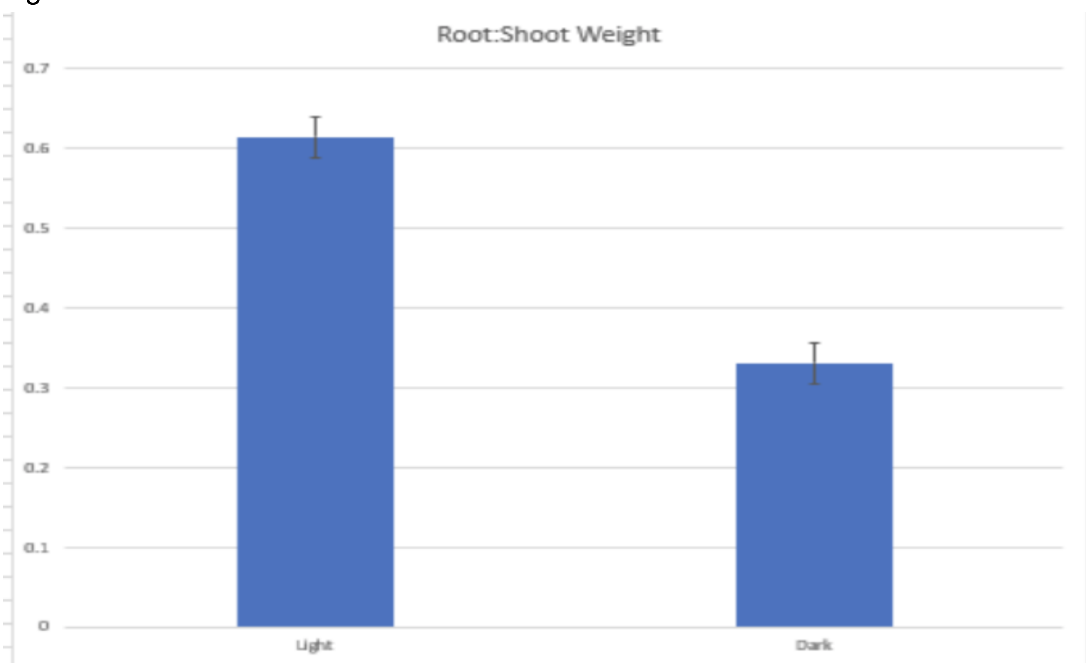


Figure Legends: Root: Shoot Length; Root:Shoot Weight

SAMPLE REPORT 3

Date submitted: 2018-10-02 09:30:50
ID: R_1CJbjRTebvuUZ1O
Course number: 103
TA: TA0002117

The effect of Light Color on the energy allocation of Buckwheat plants

Abstract

Using Buckwheat (Fagopyrum esculentum) plants, we investigated the use of red light on energy allocation. Many plants are often grown under different colors of light, and noticing this pattern we asked: how will light color affect the root:shoot ratios of the plants? We hypothesized that the buckwheat grown under red light would in comparison to the control group allocate more resources to its roots and capturing energy than investing in growth of it's shoot. After growing the plants for 2 weeks under different light conditions, there proved to be no difference in the ratio of resources allocated to each portion of the plant by the different groups, hoever there was a seemingly significant difference in overall size, with the control group plants being much larger. This result was probably skewed by the red light group's plastic filter trapping in heat and moisture, possibly smothering the plant in excess heat and water, preventing growth. Thus further experiments are likely required to ensure the accuracy of this experiment's results.

Introduction

Plants, like any organism, have limited resources available to them. How plants "spend" their resources depends on many environmental factors [Lab Manual : 2018]. Different colors of light are known to affect plant growth, with red typically being the most effective at spurring growth within filtered light colors and green the least effective, although this varies between plant species [McCoshum : 2011]. This difference between light colors is due to the different wavelengths of light that make up the different colors affects the production of different chemicals within the plant, in turn affecting the plant's overall growth and structure [McCoshum : 2011]. Knowing that changing light color will affect how well plants are able to grow and produce certain resources, how will changing light color affect a plant's resource allocation? To calculate this, we will analyze the ratio between resources allocated to the roots and resources allocated to shoots of Buckwheat (Fagopyrum esculentum) plants. A higher root-shoot ratio will typically that the plant needed to invest more in gathering energy while a lower root-shoot ratio typically means that the plant was easily nourished and could afford to allocate more towards it's growth [Lab Manual : 2018]. In this experiment, we will test the effects of receiving solely red light on the root:shoot ratios of buckwheat plants. Our hypothesis is that plants grown under red light will have higher root-shoot ratios than the plants grown under normal light (control group). HA: Root-Shoot ratios will increase under red light

Materials and Methods

Materials used in this lab included:

- Four thin, square, plastic potting containers
- Two larger, thicker plastic containers

- About 100 buckwheat seeds
- Potting soil
- Miracle grow liquid fertilizer mix
- Tap water
- Translucent red plastic

Fill the four plastic pots with potting soil, then put approximately 25 seeds in each pot, planting them just beneath the soil and spaced out within the pot. After placing the seed, add 200mL of miracle grow to each pot, then about 500 ml of water to each pot. Place the pots in containers, then place those in a greenhouse with one container holding two pots under normal sunlight and one container holding two pots under sunlight filtered through the red plastic. Leave the plants in the greenhouse for the next two weeks, giving them the same amount of water each day. In our experiment, the amount of water varied each day due to an inability to access the greenhouse during hurricane Florence. After two weeks, the plants were carefully removed from the pots using plenty of water and were washed, and from each pot 6 plants were selected at random (making 12 plants for each light color). The root lengths were measured from the tip of the root to the root-shoot junction, and the shoot lengths were measured from the root-shoot junction to the point where the leaves branch from the stem. The plants were then cut at the root-shoot junction and the leaf-stem junction and weighed the roots and the shoot of each plant.

<u>Results</u>

The mean root-shoot ratios for weight and length of the red-light group were not significantly different from the ratios of the normal-light control group. Weight: T-Stat = 0.714, df = 22, p = 0.0483 Length: T-Stat = 0.0467, df = 22, p = 0.963 It is worth noting that even though the ratios were similar, the mean values for the root and shoot length and weight of red light plants was much smaller than that of the normal light plants.

<u>Discussion</u>

The data did not support our hypothesis as the root-shoot ratios were fairly similar and weren't close to having a statistically significant difference between the two. Even though the root-shoot ratios were roughly the same, the mean of the weights and lengths had a noticeable difference. The red-light plants were on average much smaller than the control group plants, but they managed to hold the same root-shoot ratio as the control group plants. This means that the red-light plants were probably receiving enough nutrients and required sunlight, but likely had their growth stunted by a confounding factor. In the case of our study, the lurking variable that stunted the red-light plant's growth was the plastic cover, it seemed to trap heat and moisture in, possible suffocating the plants with the excess heat and water in the soil. In future experiments the red plastic should be kept well above the plants and the control should have a layer of clear plastic above it as well to avoid this problem. With the results we have however, we can infer that buckwheat plant's resource allocation is unaffected by red-light. It may also be helpful to test many other colors as well to see if they have an effect on buckwheat's resource allocation.

Literature Cited
1. McCoshum S and Kiss JZ. 2011. Green light affects blue-light-based phototropism in hypocotyls of arabidopsis thaliana. J Torrey Bot Soc 138(4):409-17.
2. Ecology & Evolution Bio 113 Lab Manual. 15-24

Figure: 1

	Root-Shoot Weight Ratio	Root-Shoot Length Ratio
Control Group (Normal Light)	0.383 ± 0.212	0.576 ± 0.156
Treatment (Red Light)	0.318 ± 0.144	0.579 ± 0.192

Figure: 2

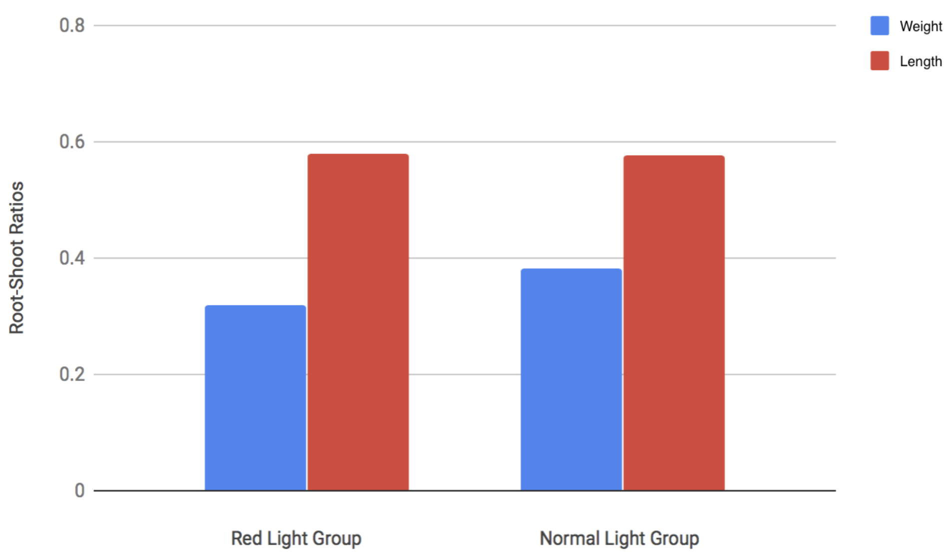


Figure Legends

Figure 1: Summarized Root-Shoot Ratio Data
Table 1: Root-Shoot Means and Standard Deviations

Sample Report 4

Date submitted: 2018-10-02 13:44:12
ID: R_4zFUfUqMTgx87oO
Course number: 103
TA: TA0002117

The effects of herbivory on the resource allocation of Pisum sativum

Abstract

Herbivory has been a predominant biotic factor in the evolution of plants for millions of years, impacting resource allocation and the trade-offs plants must go through under limited resources. The herbivory of Pisa sativum, or field peas, consists of mainly insects and acts as a dynamic resource limitation, defoliating the plant. The purpose of this experiment was to gauge the simulated effects of herbivory on field peas' resource allocation through evaluation of their root:shoot ratios. For two weeks, regular watering and sunlight was administered to two groups of field peas, although the experimental group was defoliated every three days. The control group ended up having a larger length and mass root:shoot ratio than that of the experimental which was rather unexpected. The mass ratio results ended up being statistically insignificant, although the length ratio differences did prove to be significant. Despite some experimental concerns, the evaluation did allow one to display that the biotic factor of herbivory did in fact have an effect on Pisum sativum resource allocation.

Introduction

Plants and other living organisms have learned to co-evolve overtime, adapting growth and reproduction strategies cooperatively in order to survive. The biotic factor of herbivory has been forcing plants to efficiently allocate their limited resources due to defoliation for more than 350 million years [War 2012]. Many organisms ranging from insects to mammals all rely upon the nutrients and foliage of plants as their main food source. Just as plants must adapt to the environment concerning biotic factors such as sunlight, nutrition, and precipitation, they also must adapt to the other organisms living around them. Both sets of factors are directly related to plants' strategies for resource allocation and their fitness. In this experimental design, we would like to see how the simulated presence of herbivores shape the resource allocation of Pisum sativum seedlings. The herbivores' feeding serves as an active resource limitation, defoliating the seedlings and ridding away their precious photosynthetic and reproductive organs. Due to a temporary nutrient deficiency, growth and photosynthesis may be limited not only due to the loss of the leaf organs but also due to the plant responding to the loss through defensive strategies or limiting new growth [Luxmore, 1991]. It is known that the stem and leaves of the plant are integral to new growth, support, and photosynthesis whereas the roots are key to nutrient uptake from the soil. With the simulated herbivory targeting the leaves of the seedlings, one expects the defoliation to negatively affect plant growth, inhibiting photosynthesis. A higher root:shoot ratio of the experimental group is expected due to the fact that the seedlings mat not be able to allocate as much energy into their shoots after constantly becoming defoliated, allowing them to focus on a stronger root network. This inquiry will allow us to observe the effects of a very pressing biotic factor in the environment and quantify the resource allocation of these plants based off of such stimuli.

Materials and Methods

Before conducting our experiment, a total of six plant pods containing several seeds of Pisum sativum were planted and watered. Three of these pods were designated as the control group and underwent normal watering procedures daily and the other three experimental pods were simulated to have been “eaten” by herbivores. Over a span of two weeks, the plants were regularly water and every three days the experimental group had one half of all its leaves trimmed to simulate the effects of herbivory (Note: There were two days during which the plants were unable to be watered or trimmed due to Hurricane Florence complications). After two weeks of growth and herbivory stimuli, the effects were evaluated by measuring both the mass and length root:shoot ratios of the seedlings. This was conducted by cutting the plants just below the seed shell to separate the roots from the shoots. The root lengths were measured from the tip of the longest root to the cut end and the shoot lengths were measured from the tip of the furthest leaf to the cut end as well. The masses of the respective parts were also taken. It was key to stick to consistency during this process. Following data collection, statistical tests concerning means, standard deviations, and a two sample t-test were conducted to evaluate the significance of differences between our experimental and control groups.

Results

The outcome of the experiment displayed a general trend of a higher mass and length mean root:shoot ratio in the control group over two weeks of growth. The mean root:ratios of both groups did not differ that greatly in magnitude and their standard deviations were relatively moderate. Furthermore, there was a statistically significant difference between the mean length root:shoot ratios of the experimental and control groups (t-stat = 2.24, df = 12, $p = 0.035$), but there was no statistically significant difference between the mean mass root:shoot ratios of the two groups (t-stat = 1.13, df = 12, $p = 0.272$). In both cases we do see a lower mean root:shoot ratio in the experimental group, but the statistical tests prove only the mean root:shoot ratios to be statistically different in terms of length, not mass.

Discussion

According to our alternative hypothesis, we stated that the defoliation of field peas by herbivores would negatively affect plant growth, specifically concerning the stem and leaves. Thus, we expected the experimental group to have a larger root:shoot ratio than that of our control. Our summary of data does not support this alternative hypothesis, as the root:shoot ratios, both mass and length, were higher in the control group than in the experimental group. Specifically, we found the mass root:shoot ratio differences to be statistically insignificant, but the length root:shoot ratios were determined to be significant through our statistical tests. We still can conclude that the herbivore simulation did have a minor effect on the resource allocation, the but the results show that the experimental group actually had a significantly smaller mean length root:shoot ratio. The consistent cutting of the leaves may have forced the plant to adapt and combat this cutting by quickly responding through the regrowth of the small leaves cut, increasing the shoot length [Luxmore 1991]. This provides more leaves to be used for photosynthesis and more to be available after being selectively eaten, thus resulting in a smaller root:shoot ratio than the control. Also, it is possible that the simulated herbivory forced the seedlings to completely limit their growth in anticipation that their resources would be wasted by being defoliated once again. Considering some concerns, this experiment may not have been ideal under such a short period of time as we were unable to truly observe the gradual feeding of the plants. The extremely controlled simulation of herbivory may actually not have elicited a natural response, as organisms are usually more selective than we simulated them to be. Thus, the results we obtained in the lab may not be fully germane to a natural environment. Overall, despite our alternative hypothesis not being completely supported, we can conclude with significance that the effects of herbivory on the field pea plants does negatively affect their resource allocation.

Literature Cited

1. Luxmoore, R. J. (1991). A Source-Sink Framework for Coupling Water, Carbon, and Nutrient Dynamics of Vegetation. Tree Physiology, 9(1-2): 267-280.
2. War, Abdul Rashid et al. “Mechanisms of Plant Defense against Insect Herbivores.” Plant Signaling & Behavior 7.10 (2012): 1306–1320. PMC.

Figure: 1

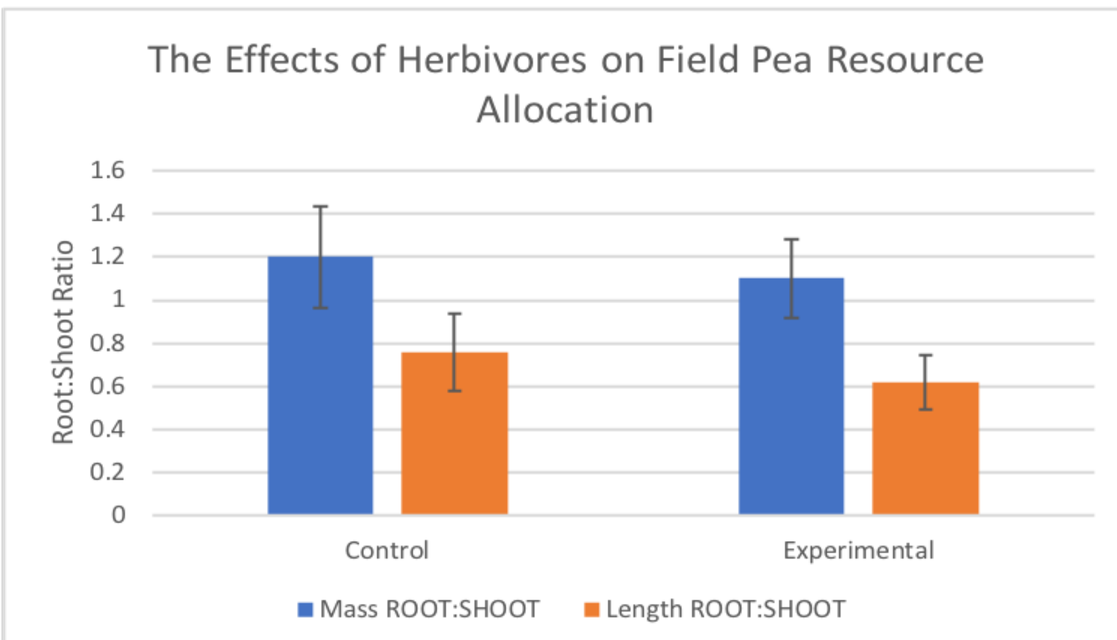


Figure: 2

Summary Table of Root:Shoot Ratios

	Control	Experimental
Avg. Length R:S	0.76 ± 0.18 cm	0.62 ± 0.13 cm
Avg. Mass R:S	1.20 ± 0.24 g	1.10 ± 0.18 g

Table 1.1 - The table displays the mean root:shoot ratios of both our control and experimental groups of field pea seedlings. The standard deviations of each sample are also included.

Figure Legends

Figure 1.1 - This bar chart displays our sumarized results of the root:shoot ratios in both our control and experimental groups of Pisa sativum. The error bars display the standard deviations of our summarized data.

Table 1.1 - The table displays the mean root:shoot ratios of both our control and experimental groups of field pea seedlings. The standard deviations of each sample are also included.

Sample Report 1 – Commented and Graded

Date submitted: 2018-10-01 12:12:18
ID: R_3gklfFTZDDajEA7
Course number: 103
TA: TA0000304

The Effect of Herbivory on Energy Allocation of Field Peas

Abstract

Resource allocation consists of plants deciding where energy should be used in their systems. This is in an effort to increase fitness and survive in an environment where these resources are limited. Plants are able to respond to their environment and change their allocation patterns in order to become more fit. In this lab we sought information on how herbivory, the consumption of plants by animals, impacted how Field Peas allocated resources between its roots and its shoots. We simulated herbivory by removing leaves and measures energy allocation by recording root:shoot ratios for mass and length. Our results indicate that herbivory has no impact on plant energy allocation. This proves to be in conflict with findings of other published studies. We believe that there were key limitations to our study that yielded these differing results and that further experimentation with methodical modification would produce results that showed the proper impact that herbivory has an energy allocation. This knowledge would be important in an agricultural context and could help farmers maximize crop yield.

Introduction

The concept of limited resources is the driving idea behind evolutionary and ecological study. How organisms battle for these resources and use them, determines many factors about them such as their location, structure, shape, and many more. One key aspect of how an organism interacts with and uses resources is energy allocation. Energy allocation is the way an organism uses its energy. For example, whether plants use more resources for root growth or for shoot growth demonstrates how a plant could allocate its energy. Organisms are generally designed to have certain energy allocation protocols, but there is a certain degree of plasticity associated with the matter. Organisms are able to adapt to a particular environment or environmental change by altering how it allocates its resources. This is all in an effort to increase fitness and survival rate in a world of limited resources [Lerdau: 1997]. In this laboratory, we explored how herbivory impacted Field Pea (Pisum sativum) energy allocation by recording root to shoot ratios. The model organism Pisum sativum was used due to its short growth cycle, ease of maintenance in a green house, and compatibility with US southeast fall climate. Herbivory is the act of herbivores damaging plant tissue, via eating, and therefore removing parts of the plants, such as leaves, that are important in energy harvesting [Belsky: 1986]. This issue is prevalent in agricultural settings and could provide insight to agrarian companies and peoples looking for methods to provide optimum plant growth. Field Peas specifically, are extremely valuble to the agriculture of one of the largest nations in the world, India. [Singh: 2016]. Energy allocation affects how a plant grows which also affects its usefulness to humans. We predicted that if field peas were exposed to conditions that resembled herbivory, then the plant would

Commented [ADJ1]: You did very well at laying out a coherent experiment. What I struggled most with was how the flow switched from one idea to another for no obvious reason. As you revise, focus on making the story flow from one main idea to the next without hopping around.

There are some technical corrections needed, but those are much less of a concern.

Overall score: Needs minor revisions/3

Commented [ADJ2]: How could you reorganize the Introduction so it flows more smoothly from one idea to the next? Take a look back at the article we read last week; how did those authors organize the introduction?

Commented [ADJ3]: How could this be revised to make it more concise and direct? Does this need to be supported by a citation?

Commented [ADJ4]: Is this the right section for this kind of information? Look at p. 32 of the Resource Guide.

allocate more energy to the shoots and that root: shoot ratio would decrease relative to the control.

Materials and Methods

The first part of the experiment consisted of planting the field peas. The seeds were soaked in water for 30 minutes before planting. While the seeds were soaking, we designated four pots to be the control group and four pots to be the experimental group. All eight pots were filled to the top with vermiculite, pre-watered, and given 50 mL of miracle grow. In each pot we made nine equally spaced intentions about 2-3 times the size of the seeds, and in each indention placed three seeds. After gently covering the seeds, we placed all eight pots in the green house. All pots were soaked fully with water once a day for a week. After one week, the herbivory simulation was performed on the four experimental pots. For each plant that was growing in the experimental pots, half of the leaves were removed. Each pot was subsequently soaked with water daily for one more week before data collection took place. To collect data, we randomly selected five plants from the control and five plants from the experimental group. For each plant, we measured total mass, root mass, shoot mass, and calculated root:shoot ratios. We also measures root length, shoot length, and calculated root:shoot ratios for each plant. Average mass root:shoot ratios and standard deviations were subsequently calculated for the experimental group and the control. Additionally, average length root:shoot ratios and standard deviations were calculated for the experimental group and the control. The mass root:shoot ratios of the two groups were compared using a two tailed t-test, and the length roots:shoot ratios of the two groups were compared using a two-tailed t-test.

Commented [ADJ5]: You did a good job providing a narrative of what you did.

Results

Figure 1 compares the root:shoot mass ratios and indicates that the average root:shoot ratio of the experimental group, 0.80±0.10, is not significantly different from the average root:shoot ratio of the control group, 0.71±0.20 ($P>0.05$). Figure 2 compares the root:shoot length ratios and indicates that the average root:shoot ratio of the experimental group, 0.66±0.07, is not significantly different from the average root:shoot ratio of the control group, 0.63±0.08 ($P>0.05$).

Commented [ADJ6]: Should this section be past or present tense?

Commented [ADJ7]: Is this the right way to report results of a statistical comparison? Look at p. 33 of the Resource Guide.

Discussion

The results of the experiment do not support our original hypothesis that herbivory decreases root:shoot ratios. The data indicates that there is no relationship between herbivory and how Field Peas allocate energy between their roots and their shoots. This is significant in an agricultural context because it implies that farmers need not concern themselves with animals and insects eating parts of their crops. It further suggests that herbivory does not impact the fitness of the plant as the plant made no effort to adapt to the change. This conclusion is not supported by published studies and we believe several key limitations gave way to our divergent results. One study investigating the impact of insecticides found that decreasing insect herbivory increased plant height and overall size and concluded that herbivory has a considerable effect on plants [Wilbur: 2013]. This contrasts our data as it shows plants do not exist without response to herbivory. Another study states that in response to attack from herbivorious insects, plants typically move carbohydrates and recourses to the roots in an effort to minimize nutrient loss. [Schultz: 2013]. This means that root to shoot ratio would increase, which is

Commented [ADJ8]: Again, look at the tense.

Commented [ADJ9]: I do not follow your logic here. Can you be more specific?

contradictory to our findings. It is apparent that herbivory should have an impact on energy allocation and thusly should have impacted our root:shoot ratios. Further experimentation that addresses the limitations of the study should be carried out. We believe that it is possible that one week was not long enough for the effects of the herbivory to be seen and that the herbivory was not intense enough to elicit the appropriate response. We were limited by time and a fear that too much leave removal would prove fatal to our peas. A study carried out over a month with over 75% leaf removal every week would have been an ideal experimental environment. With these experimental changes we believe that a relationship between herbivory and plant resources allocation will be apparent. After this data is procured, the findings would confirm the large impact herbivory has on allocation and therefore plant fitness. Limiting herbivory in plants has been shown to greatly increase fitness [Wilbur: 2016] and more data and information to how this process occurs could prove valuable in increasing crop yields.

Commented [ADJ10]: This is good. You make clear your rationale for an experimental decision, then build on it when describing what you could do differently.

Literature Cited

Commented [ADJ11]: Good use of a range of literature sources.

1. Lerdau, Manuel, and Jonathon Gershenzon. "Allocation Theory and." Plant resource allocation (1997): 265.
2. Belsky, A. J. "Does herbivory benefit plants? A review of the evidence." The American Naturalist 127.6 (1986): 870-892.
3. Schultz, Jack C., et al. "Flexible resource allocation during plant defense responses." Frontiers in plant science 4 (2013): 324.
4. Hufbauer, Ruth, et al. "The effect of insect herbivory on the growth and fitness of introduced Verbascum thapsus L." Neobiota 19 (2013): 21.
5. Singh, Sandeep Kumar, et al. "Estimation of correlation coefficient among yield and attributing traits of field pea (Pisum sativum L.)." Legume Research 41.1 (2018): 20-26.

Figure: 1

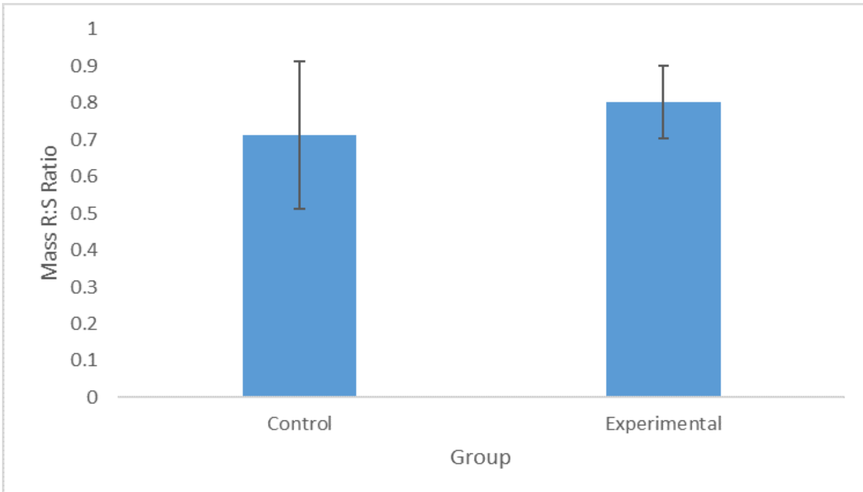


Figure: 2

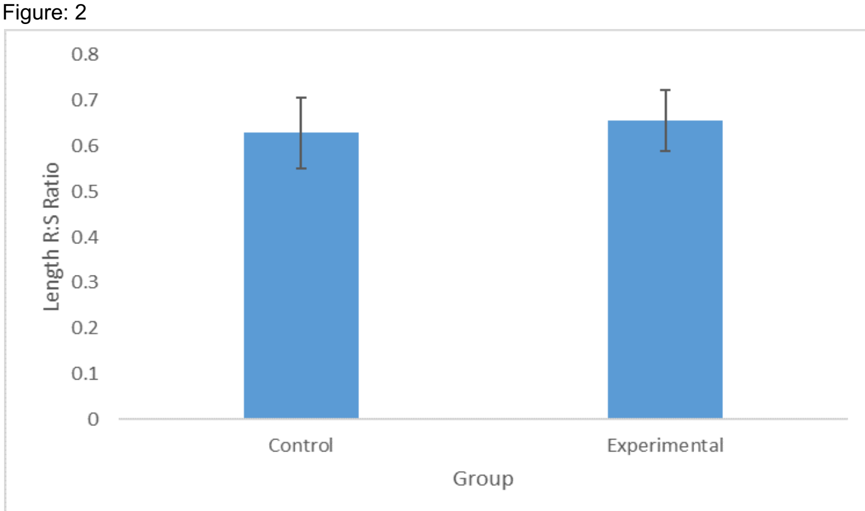


Figure Legends

Figure 1. A comparison of average mass root:shoot ratios for the control and experimental groups. Figure 2. A comparison of average length root:shoot ratios for the control and experimental groups.

Commented [ADJ12]: Are these explanations detailed enough that someone outside your lab group could interpret them? Hint: look at the example in the Resource Guide on p. 41, or one of the figure legends in the article we read last week.

SAMPLE REPORT 2 – COMMENTED AND GRADED

Date submitted: 2018-10-01 07:10:44
ID: R_2AkJShlNazuVxtv
Course number: 103
TA: TA0000304

Resource and Energy Allocation in Vigna radiata

Abstract

Vigna radiata is a plant which allocated resources to roots or shoots depending on the environment in which it is placed. This experiment looks at this particular plant's ability to allocate resources when placed in normal sun exposure as well as in a shaded area. We placed plants in both normal sunlight exposure and under a shade, then measured root:shoot ratios after the plants grew. In this experiment we found that those plants exposed to less light had a larger root:shoot ratio, as we expected them to.

Introduction

A vital aspect of a plant's life is uptake and allocation of resources. When certain abiotic factors in a plant's environment are changed, the plant also changes its physical form in order to gain appropriate amounts of nutrients and continue to live. This is called Resource Allocation; Resource Allocation happens on the phenotypic level when a plant must make a change in order to be more fit for the environment in which it lives. Such patterns of allocation "play a pivotal role in life history evolution and functional plant ecology" [Bazzaz: 1997]. Plants being exposed to various amounts of light will cause variation in the ways they allocate resources in order to be most fit for their environments. Vigna radiata was an appropriate model organism for this experiment because it is a relatively quickly adapting plant, which allowed easy viewing of its ability to allocate resources. Since the shoot is the part of the plant responsible for photosynthetic processes and a larger root:shoot ratio in a darker area will allow the plant to survive as well as those in areas with greater amounts of sunlight, those plants exposed to less light will allocate more energy for shoot length than those exposed to more light.

Materials and Methods

For this experiment we first soaked 50-60 seeds from the model organism in water prior to planting them. We then placed the seeds in pre-soaked vermiculite with 50mg of "Miracle Gro" in each individual seed hole (six bins of about 6-10 seeds in each bin). We placed three bins on one tray of plants in a greenhouse with natural light exposure, and three under a shade cover with much less light exposure. We watered the plants daily for two weeks, and after they grew appropriately we began to measure the root:shoot ratios. We gathered ten plants from the natural light group and ten from the shaded group. We first weighed the plants respectively, then separated the roots from the shoot (precision and consistency is crucial here for the integrity of the experiment). We then weighed the roots and the shoots of each respective group and calculated weight ratios, after this we measured the length of root and shoot and calculated that ratio as well. Last, measure the maximum root and shoot lengths of each group and record the mean values for both of the plant groups.

Commented [ADJ13]: This is a good initial submission because it contains all of the data and ideas that you need for a great final report. You need to refine some of what you have to get there.

The logical connections between some of your ideas are missing, and several times you jump from idea to idea too soon. You need to integrate your outside resources better. Also, you do not refer to your figures anywhere, and have several places where you include information or ideas that seem not to go anywhere.

Pay special attention to what information goes where, and whether or not you can use direct quotes.

Overall score: needs major revisions/2

Commented [ADJ14]: What is your logic for this?

Commented [ADJ15]:

Commented [ADJ16]: Are direct quotes allowed?

Commented [ADJ17]: Is this the right section for this kind of information? Look at p. 32 of the Resource Guide.

Commented [ADJ18]: I am having trouble following your logic here. It seems like part of your rationale is missing.

Commented [ADJ19]: Why did you mention this? It is not something you bring up later as important.

Results

The results of this experiment showed a significant difference for weight ($t= 13.378$, $df=4$, $p= 0.000181$) as well as height ($t= 3.983$, $df=4$, $p=0.016353$) with an alpha level of 0.05. The graphs show the differences in both ratios of root:shoot weight and length in the light and dark areas. To calculate significance we used a two-sample t-test and an alpha level of 0.05.

Discussion

Our results supported our hypothesis, as the p-values for both the height and weight ratios were less than the alpha level of 0.05. These data show that the plants which were exposed to less light allocate more energy and resources to shoot length and growth in order to maximize photosynthetic ability. From this experiment we can conclude that plants in generally darker areas will tend to allocate more resources towards shoot growth, which could mean less energy for appropriate root growth. This adaptation can be beneficial for plants needing to increase surface area for photosynthesis, but it could also be dangerous in that less resources will be allocated toward root growth which is also a key factor in a plant's survival and vitality. Knowledge regarding the adaptability of plants can allow researchers to understand exactly how a specific plant will survive in certain, varying environments. This can be essential and helpful in agricultural farming, as we are now able to show which environment a plant will thrive in and have the optimized crop yield. Since plants change so rapidly phenotypically, technologies such as underground x-rays are being created in order to gain a better understanding of plant structure and architecture. Such techniques will "provide a better understanding of how overall plant architecture is regulated...and how best precision agriculture can be exploited to optimize plant growth and seed/fruit development" [Bennett, 2012]. By understanding resource allocation, we can grow crops in highly conducive areas and soils in order to generate the highest possible crop yield. In the future this experiment could be done with varying levels of light exposure (rather than just two) in order to better understand the levels of allocation.

Literature Cited

1.Fakhri A. Bazzaz, John Grace. 1997. Plant Resource Allocation. San Diego: Academic Press. 306 pp.

2.Emma Bennett, Jeremy A. Roberts and Carol Wagstaff. 2012. Manipulating resource allocation in plants. Journal of Experimental Botany. 63: 3391-3400.

Commented [ADJ20]: Where do you reference your figures by number? How do we know which one to look at?

Commented [ADJ21]: Does this belong in this section? BioCore Resource Guide, p. 36.

Commented [ADJ22]: Which verb tense is correct? You jump from past to present to future within individual sentences.

Commented [ADJ23]: This is very vague and generic. Look back at the article we read last week. How did they put their results into a larger context?

Commented [ADJ24]: This sentence seems like you are trying to force a connection between the reference and your conclusions. How can you revise this sentence so that Bennett 2012 is supporting a claim or idea you are presenting, instead of just being tacked on?

Commented [ADJ25]: Are you allowed to use direct quotes? See p. 34 of Resource Guide.

Figure: 1

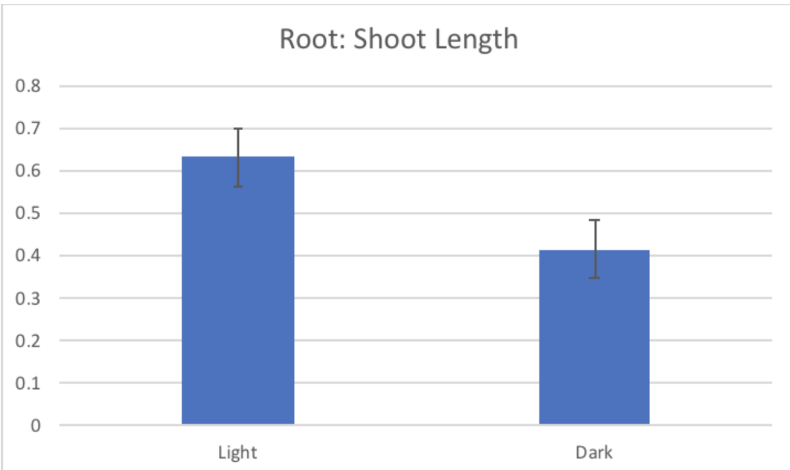


Figure: 2

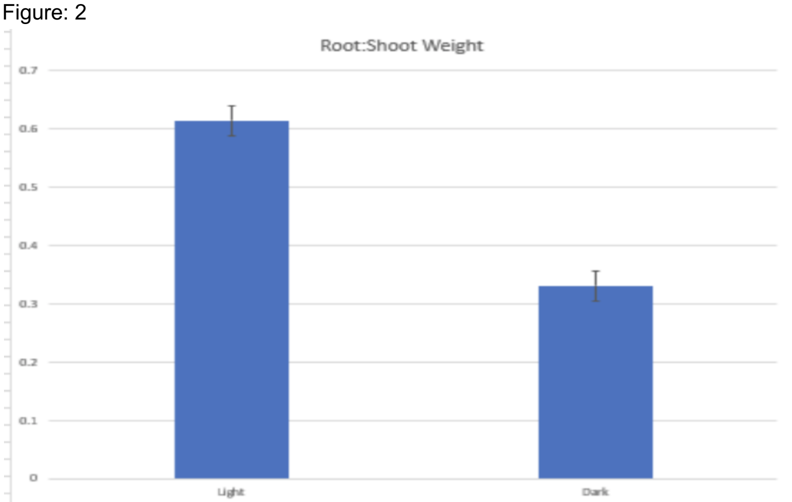


Figure Legends: Root: Shoot Length; Root:Shoot Weight

Commented [ADJ26]: Are these explanations detailed enough that someone outside your lab group could interpret them?

Sample Report 3 – Commented and Graded

Date submitted: 2018-10-02 09:30:50
ID: R_1CJbjRTebvuUZ1O
Course number: 103
TA: TA0002117

The effect of Light Color on the energy allocation of Buckwheat plants

Abstract

Using Buckwheat (Fagopyrum esculentum) plants, we investigated the use of red light on energy allocation. Many plants are often grown under different colors of light, and noticing this pattern we asked: how will light color affect the root:shoot ratios of the plants? We hypothesized that the buckwheat grown under red light would in comparison to the control group allocate more resources to its roots and capturing energy than investing in growth of it's shoot. After growing the plants for 2 weeks under different light conditions, there proved to be no difference in the ratio of resources allocated to each portion of the plant by the different groups, hoever there was a seemingly significant difference in overall size, with the control group plants being much larger. This result was probably skewed by the red light group's plastic filter trapping in heat and moisture, possibly smothering the plant in excess heat and water, preventing growth. Thus further experiments are likely required to ensure the accuracy of this experiment's results.

Introduction

Plants, like any organism, have limited resources available to them. How plants "spend" their resources depends on many environmental factors [Lab Manual : 2018]. Different colors of light are known to affect plant growth, with red typically being the most effective at spurring growth within filtered light colors and green the least effective, although this varies between plant species [McCoshum : 2011]. This difference between light colors is due to the different wavelengths of light that make up the different colors affects the production of different chemicals within the plant, in turn affecting the plant's overall growth and structure [McCoshum : 2011]. Knowing that changing light color will affect how well plants are able to grow and produce certain resources, how will changing light color affect a plant's resource allocation? To calculate this, we will analyze the ratio between resources allocated to the roots and resources allocated to shoots of Buckwheat (Fagopyrum esculentum) plants. A higher root-shoot ratio will typically that the plant needed to invest more in gathering energy while a lower root-shoot ratio typically means that the plant was easily nourished and could afford to allocate more towards it's growth [Lab Manual : 2018]. In this experiment, we will test the effects of receiving solely red light on the root:shoot ratios of buckwheat plants. Our hypothesis is that plants grown under red light will have higher root-shoot ratios than the plants grown under normal light (control group). HA: Root-Shoot ratios will increase under red light

Materials and Methods

Materials used in this lab included:

- Four thin, square, plastic potting containers
- Two larger, thicker plastic containers

Commented [ADJ27]: You are missing any literature citations that connect your Introduction and Discussion; this is one of the Basic Criteria.
You have a good basic description of your experiment.

What you need to work on for the revisions is:
- Making sure your reasons for your choices in the experiment are clear.
- How you show your results matches the requirements in the BioCore Resource Guide.

Overall score: Unacceptable/1 (missing citations)

Commented [ADJ28]: Can you be more specific? I'm not sure how this points to a new question; seems like you are just repeating what they did.

Commented [ADJ29]: Read this again; are you sure this is what you meant to say?

Commented [ADJ30]: Is this the right format? Look at p. 39 of Biocore RG

- About 100 buckwheat seeds
- Potting soil
- Miracle grow liquid fertilizer mix
- Tap water
- Translucent red plastic

Fill the four plastic pots with potting soil, then put approximately 25 seeds in each pot, planting them just beneath the soil and spaced out within the pot. After placing the seed, add 200mL of miracle grow to each pot, then about 500 ml of water to each pot. Place the pots in containers, then place those in a greenhouse with one container holding two pots under normal sunlight and one container holding two pots under sunlight filtered through the red plastic. Leave the plants in the greenhouse for the next two weeks, giving them the same amount of water each day. In our experiment, the amount of water varied each day due to an inability to access the greenhouse during hurricane Florence. After two weeks, the plants were carefully removed from the pots using plenty of water and were washed, and from each pot 6 plants were selected at random (making 12 plants for each light color). The root lengths were measured from the tip of the root to the root-shoot junction, and the shoot lengths were measured from the root-shoot junction to the point where the leaves branch from the stem. The plants were then cut at the root-shoot junction and the leaf-stem junction and weighed the roots and the shoot of each plant.

Commented [ADJ31]: Look at the article we read last week as a class. How is their Methods section organized? What can you change to make this clearer, and more like what we saw published?

<u>Results</u>

The mean root-shoot ratios for weight and length of the red-light group were not significantly different from the ratios of the normal-light control group. Weight: T-Stat = 0.714, df = 22, p = 0.0483 Length: T-Stat = 0.0467, df = 22, p = 0.963 It is worth noting that even though the ratios were similar, the mean values for the root and shoot length and weight of red light plants was much smaller than that of the normal light plants.

Commented [ADJ32]: Good work highlighting the relevance of this observation.

<u>Discussion</u>

The data did not support our hypothesis as the root-shoot ratios were fairly similar and weren't close to having a statistically significant difference between the two. Even though the root-shoot ratios were roughly the same, the mean of the weights and lengths had a noticeable difference. The red-light plants were on average much smaller than the control group plants, but they managed to hold the same root-shoot ratio as the control group plants. This means that the red-light plants were probably receiving enough nutrients and required sunlight, but likely had their growth stunted by a confounding factor. In the case of our study, the lurking variable that stunted the red-light plant's growth was the plastic cover, it seemed to trap heat and moisture in, possible suffocating the plants with the excess heat and water in the soil. In future experiments the red plastic should be kept well above the plants and the control should have a layer of clear plastic above it as well to avoid this problem. With the results we have however, we can infer that buckwheat plant's resource allocation is unaffected by red-light. It may also be helpful to test many other colors as well to see if they have an effect on buckwheat's resource allocation.

Commented [ADJ33]: Think about this some more. Where do you show us this information specifically?

Commented [ADJ34]: This is an interesting claim. What evidence or observations do you have to back them up?

Literature Cited

1. McCoshum S and Kiss JZ. 2011. Green light affects blue-light-based phototropism in hypocotyls of arabidopsis thaliana. J Torrey Bot Soc 138(4):409-17.
2. Ecology & Evolution Bio 113 Lab Manual. 15-24

Commented [ADJ35]: Is this the correct format described in the Resource Guide?

Figure: 1

	Root-Shoot Weight Ratio	Root-Shoot Length Ratio
Control Group (Normal Light)	0.383 ± 0.212	0.576 ± 0.156
Treatment (Red Light)	0.318 ± 0.144	0.579 ± 0.192

Figure: 2

Commented [ADJ36]: This figure is incomplete; what data points are missing?

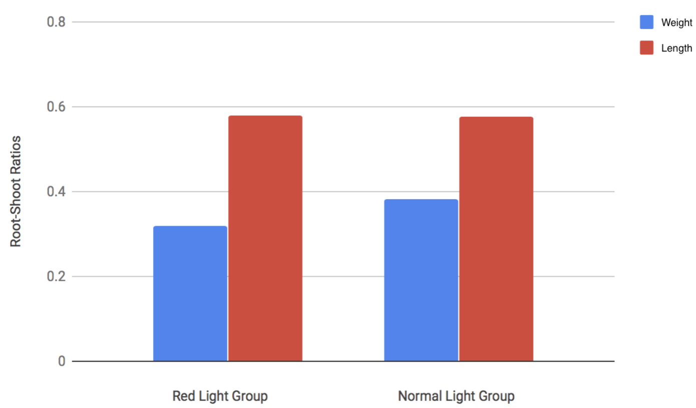


Figure Legends

Figure 1: Summarized Root-Shoot Ratio Data
Table 1: Root-Shoot Means and Standard Deviations

Commented [ADJ37]: Are these explanations detailed enough that someone outside your lab group could interpret them? Why do we need to see the table and the figure both?

Sample Report 4 – Commented and Graded

Date submitted: 2018-10-02 13:44:12
ID: R_4zFUfUqMTgx87oO
Course number: 103
TA: TA0002117

The effects of herbivory on the resource allocation of Pisum sativum

Commented [ADJ38]:
VERY nicely done. You put a lot of work into making changes like I suggested on the initial submission, and this is much improved.

If you want to make the next report even better, see if you can provide even more support from outside sources in the Introduction and Discussion.

Also, watch out for making leaps in logic; you have good ideas but sometimes did not provide clear reasoning connecting them together.

Overall score: Acceptable/4

Abstract

Herbivory has been a predominant biotic factor in the evolution of plants for millions of years, impacting resource allocation and the trade-offs plants must go through under limited resources. The herbivory of Pisa sativum, or field peas, consists of mainly insects and acts as a dynamic resource limitation, defoliating the plant. The purpose of this experiment was to gauge the simulated effects of herbivory on field peas' resource allocation through evaluation of their root:shoot ratios. For two weeks, regular watering and sunlight was administered to two groups of field peas, although the experimental group was defoliated every three days. The control group ended up having a larger length and mass root:shoot ratio than that of the experimental which was rather unexpected. The mass ratio results ended up being statistically insignificant, although the length ratio differences did prove to be significant. Despite some experimental concerns, the evaluation did allow one to display that the biotic factor of herbivory did in fact have an effect on Pisum sativum resource allocation.

Introduction

Plants and other living organisms have learned to co-evolve overtime, adapting growth and reproduction strategies cooperatively in order to survive. The biotic factor of herbivory has been forcing plants to efficiently allocate their limited resources due to defoliation for more than 350 million years [War 2012]. Many organisms ranging from insects to mammals all rely upon the nutrients and foliage of plants as their main food source. Just as plants must adapt to the environment concerning biotic factors such as sunlight, nutrition, and precipitation, they also must adapt to the other organisms living around them. Both sets of factors are directly related to plants' strategies for resource allocation and their fitness. In this experimental design, we would like to see how the simulated presence of herbivores shape the resource allocation of Pisum sativum seedlings. The herbivores' feeding serves as an active resource limitation, defoliating the seedlings and ridding away their precious photosynthetic and reproductive organs. Due to a temporary nutrient deficiency, growth and photosynthesis may be limited not only due to the loss of the leaf organs but also due to the plant responding to the loss through defensive strategies or limiting new growth [Luxmore, 1991]. It is known that the stem and leaves of the plant are integral to new growth, support, and photosynthesis whereas the roots are key to nutrient uptake from the soil. With the simulated herbivory targeting the leaves of the seedlings, one expects the defoliation to negatively affect plant growth, inhibiting photosynthesis. A higher root:shoot ratio of the experimental group is expected due to the fact that the seedlings mat not be able to allocate as much energy into their shoots after constantly becoming defoliated, allowing them to focus on a stronger root network. This inquiry will allow us to observe the

Commented [ADJ39]: Is this really telling us something new that you did not say in the previous sentences?

effects of a very pressing biotic factor in the environment and quantify the resource allocation of these plants based off of such stimuli.

Materials and Methods

Before conducting our experiment, a total of six plant pods containing several seeds of Pisum sativum were planted and watered. Three of these pods were designated as the control group and underwent normal watering procedures daily and the other three experimental pods were simulated to have been "eaten" by herbivores. Over a span of two weeks, the plants were regularly water and every three days the experimental group had one half of all its leaves trimmed to simulate the effects of herbivory (Note: There were two days during which the plants were unable to be watered or trimmed due to Hurricane Florence complications). After two weeks of growth and herbivory stimuli, the effects were evaluated by measuring both the mass and length root:shoot ratios of the seedlings. This was conducted by cutting the plants just below the seed shell to separate the roots from the shoots. The root lengths were measured from the tip of the longest root to the cut end and the shoot lengths were measured from the tip of the furthest leaf to the cut end as well. The masses of the respective parts were also taken. It was key to stick to consistency during this process. Following data collection, statistical tests concerning means, standard deviations, and a two sample t-test were conducted to evaluate the significance of differences between our experimental and control groups.

Results

The outcome of the experiment displayed a general trend of a higher mass and length mean root:shoot ratio in the control group over two weeks of growth. The mean root:ratios of both groups did not differ that greatly in magnitude and their standard deviations were relatively moderate. Furthermore, there was a statistically significant difference between the mean length root:shoot ratios of the experimental and control groups (t-stat = 2.24, df = 12, $p = 0.035$), but there was no statistically significant difference between the mean mass root:shoot ratios of the two groups (t-stat = 1.13, df = 12, $p = 0.272$). In both cases we do see a lower mean root:shoot ratio in the experimental group, but the statistical tests prove only the mean root:shoot ratios to be statistically different in terms of length, not mass.

Discussion

According to our alternative hypothesis, we stated that the defoliation of field peas by herbivores would negatively affect plant growth, specifically concerning the stem and leaves. Thus, we expected the experimental group to have a larger root:shoot ratio than that of our control. Our summary of data does not support this alternative hypothesis, as the root:shoot ratios, both mass and length, were higher in the control group than in the experimental group. Specifically, we found the mass root:shoot ratio differences to be statistically insignificant, but the length root:shoot ratios were determined to be significant through our statistical tests. We still can conclude that the herbivore simulation did have a minor effect on the resource allocation, the but the results show that the experimental group actually had a significantly smaller mean length root:shoot ratio. The consistent cutting of the leaves may have forced the plant to adapt and combat this cutting by quickly responding through the regrowth of the small leaves cut, increasing the shoot length [Luxmore 1991]. This provides more leaves to be used for

Commented [ADJ40]: This explains what your research question is, but it does not really make your hypothesis clear. Is there a way to revise this (maybe with the previous sentence) to make what you tested more obvious?

Commented [ADJ41]: How did you do that?

Commented [ADJ42]: I like how you organized your summary of the outcomes in Results, then discussed the implications in the same order in the Discussion.

Commented [ADJ43]: Take this thought one further step. What physically changes in the pea plants when R:S length ratio goes down. Which parts of growth are slowing down or speeding up? Adding a bit more interpretation would help connect your observations with the following sentences why herbivory causes that.

photosynthesis and more to be available after being selectively eaten, thus resulting in a smaller root:shoot ratio than the control. Also, it is possible that the simulated herbivory forced the seedlings to completely limit their growth in anticipation that their resources would be wasted by being defoliated once again. Considering some concerns, this experiment may not have been ideal under such a short period of time as we were unable to truly observe the gradual feeding of the plants. The extremely controlled simulation of herbivory may actually not have elicited a natural response, as organisms are usually more selective than we simulated them to be. Thus, the results we obtained in the lab may not be fully germane to a natural environment. Overall, despite our alternative hypothesis not being completely supported, we can conclude with significance that the effects of herbivory on the field pea plants does negatively affect their resource allocation.

Commented [ADJ44]: You did a nice job here splitting apart the significant change from the direction of change.

Literature Cited

1. Luxmoore, R. J. (1991). A Source-Sink Framework for Coupling Water, Carbon, and Nutrient Dynamics of Vegetation. Tree Physiology, 9(1-2): 267-280.
2. War, Abdul Rashid et al. "Mechanisms of Plant Defense against Insect Herbivores." Plant Signaling & Behavior 7.10 (2012): 1306–1320. PMC.

Figure: 1

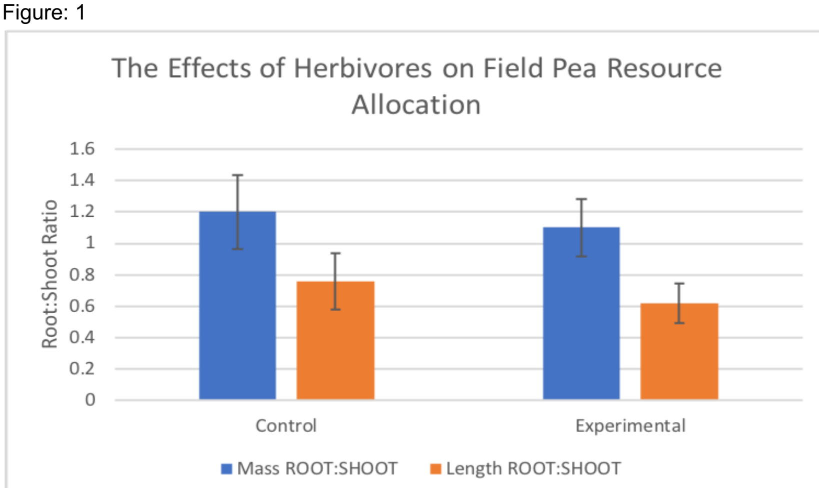


Figure: 2

Summary Table of Root:Shoot Ratios

	Control	Experimental
Avg. Length R:S	0.76 ± 0.18 cm	0.62 ± 0.13 cm
Avg. Mass R:S	1.20 ± 0.24 g	1.10 ± 0.18 g

Table 1.1 - The table displays the mean root:shoot ratios of both our control and experimental groups of field pea seedlings. The standard deviations of each sample are also included.

Figure Legends

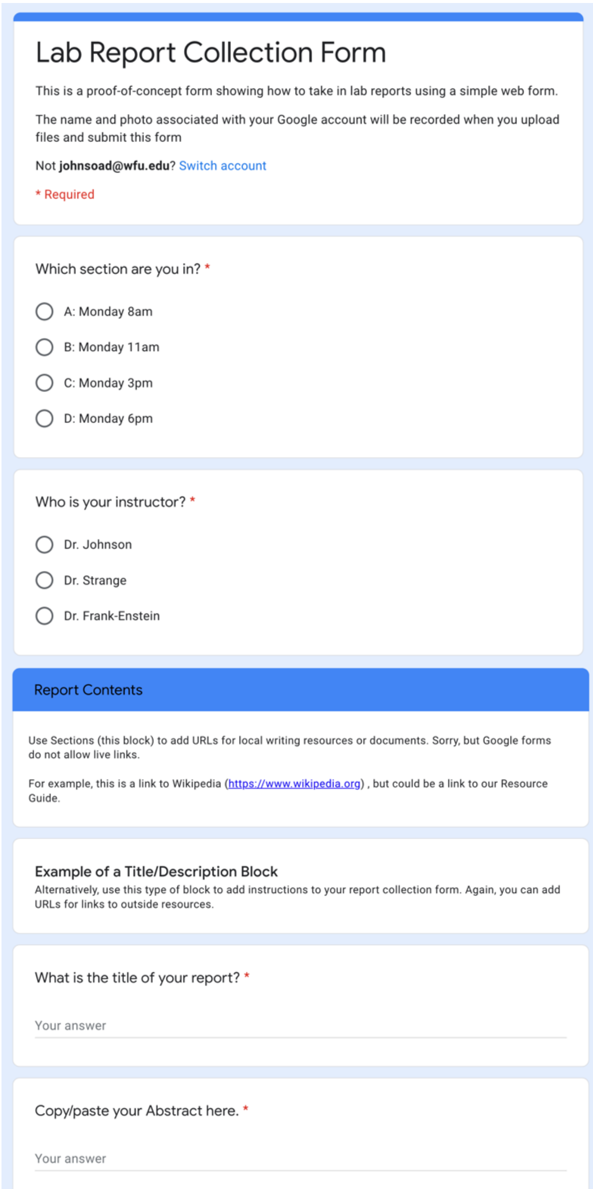
Figure 1.1 - This bar chart displays our sumarized results of the root:shoot ratios in both our control and experimental groups of Pisa sativum. The error bars display the standard deviations of our summarized data.

Table 1.1 - The table displays the mean root:shoot ratios of both our control and experimental groups of field pea seedlings. The standard deviations of each sample are also included.

Commented [ADJ45]: Why do we need to see the table and the figure both?

Supplement 3: Sample Google Lab Report Collection Form

Even simple web forms can provide automated support that reduces instructor workload. This Google survey has mandatory questions that enforce our basic content requirements and prevent students from submitting partial or incomplete reports. This removes the need to handle and comment on partial work.



Lab Report Collection Form

This is a proof-of-concept form showing how to take in lab reports using a simple web form.

The name and photo associated with your Google account will be recorded when you upload files and submit this form

Not **johnsoad@wfu.edu**? Switch account

* Required

Which section are you in? *

- A: Monday 8am
- B: Monday 11am
- C: Monday 3pm
- D: Monday 6pm

Who is your instructor? *

- Dr. Johnson
- Dr. Strange
- Dr. Frank-Enstein

Report Contents

Use Sections (this block) to add URLs for local writing resources or documents. Sorry, but Google forms do not allow live links.

For example, this is a link to Wikipedia (https://www.wikipedia.org) , but could be a link to our Resource Guide.

Example of a Title/Description Block

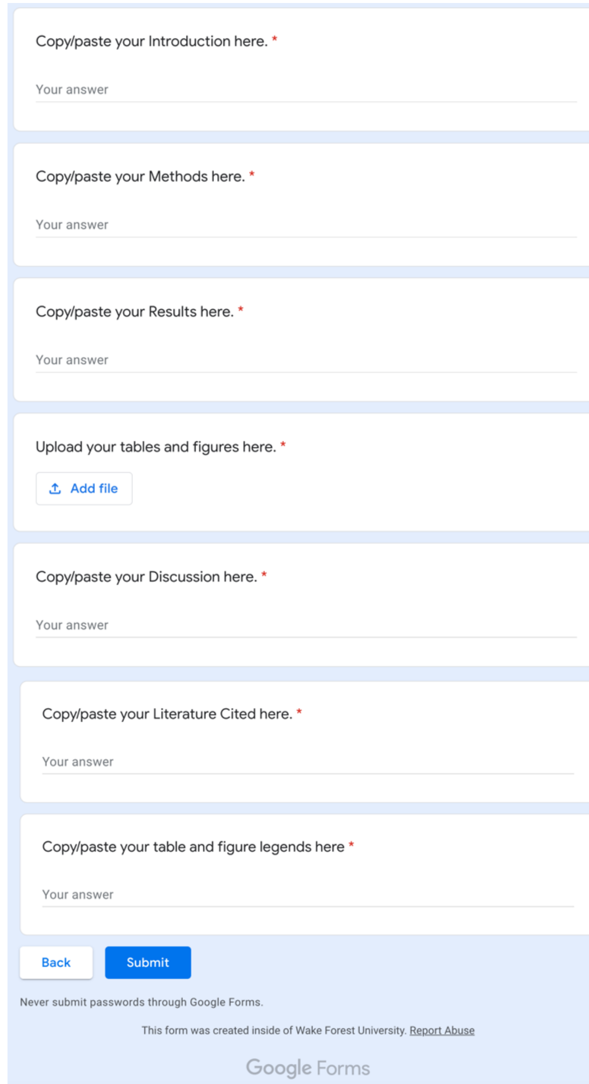
Alternatively, use this type of block to add instructions to your report collection form. Again, you can add URLs for links to outside resources.

What is the title of your report? *

Your answer

Copy/paste your Abstract here. *

Your answer



Copy/paste your Introduction here. *

Your answer

Copy/paste your Methods here. *

Your answer

Copy/paste your Results here. *

Your answer

Upload your tables and figures here. *

Add file

Copy/paste your Discussion here. *

Your answer

Copy/paste your Literature Cited here. *

Your answer

Copy/paste your table and figure legends here *

Your answer

Back Submit

Never submit passwords through Google Forms.

This form was created inside of Wake Forest University. Report Abuse

Google Forms

Forms-based submission has other benefits. Entries are time-stamped, which makes late submissions obvious. Reports are exported as a CSV data matrix with each report section in a separate column. This makes it easier to find reports with similar wording or compare multiple reports simultaneously. The individual full-text reports can be reconstructed from the CSV data file using an MS Word template plus the Mail Merge function. Re-assembled reports are all in the same format, and ready for commenting.

Supplement 4: GTA Training Guide

Grading Lab Reports

Instructional Goals

One of the department's curricular goals is to help our students develop good scientific communication skills (both written and oral.) Why do we put so much emphasis on writing? First, scientific communication is an **essential professional skill** that is best developed through routine writing. Second, writing is a **proven way to foster deeper learning**.

As a GTA you play an essential, central role in this process. You will be grading more of our students' writing than most faculty do. You also will help our students develop the foundational communication skills that they can build on in the higher level courses.

For several years we have been working to improve how we teach and grade students' scientific writing and make the process more evidence based. How we teach writing currently is based on proven practices from the WAC/WID (writing across the curriculum and writing in the disciplines), research evidence, and locally collected data.

What do we mean by "evidence-based?" For example, we know from published research that just copy-editing a student's report or telling them a list of things to "fix" only helps them earn a better grade on that one assignment. It does not help students learn how to THINK about their writing as a process. Knowing this, we have moved away from a point-by-point rubric (checklist or judgement-oriented grading) towards fostering student improvement over time (coaching mentality.)

We have practical goals for our approach to writing training too. We want to:

- Minimize GTA grading workload by increasing your time-efficiency;
- Identify sustainable, robust data sources that we can use to:
    - Monitor student progress over time;
    - Ensure consistency between instructors;
    - Improve our teaching processes.
- Identify ways to incorporate automated support for routine activities. GTAs still grade reports, but some repetitive tasks that were done by hand in the past now can be done by computers, so GTAs can focus on higher level writing support.

Student Training & Practice Activities

Students complete three specific training activities.

1. Reading, marking up, and discussing primary literature.
2. Annotating text excerpts.
3. Peer reviews of lab reports.

Each activity provides us with actionable data that we use to assess student progress and instructional impact overall. These three student activities are described in other handouts. **GTAs should not eliminate or modify these three activities.** This handout focuses on the lab reports themselves.

Logistics

What Goes In Lab Reports

General requirements and format are the same for all BioCore lab courses. They are described in detail in the **BioCore Resource Guide**, a 60+ page book that we print and give to TAs and students in BIO150 (the first course in the 2-semester sequence). A PDF version of the Resource Guide also is posted online in Canvas.

- **GTAs must read the Resource Guide closely** before grading reports the first time, and
- We STRONGLY urge every GTA to review the report grading guidelines again each semester before they start grading.

GTAs should not change format, requirements, due dates, or other parts of lab reports without prior approval by the Lab Coordinator and Faculty Instructor of Record. Doing so is grounds to revoke your assistantship.

When & How Reports Are Submitted and Returned

We only accept student lab reports by electronic submission to Canvas. **Canvas time-stamps and stores reports in a secure database**. Students cannot easily claim that a report was handed in then lost.

Other portals may become available through research projects; for example, SAWHET (STEM Automated Writing Help Tool) is a past example of an alternate online portal. The link for any alternate portal will be posted in Canvas.

Reports must be submitted as MS Word documents. We do not accept other formats because GTAs must use the Comments function in MS Word to provide their feedback on reports. Reports with comments attached are sent back to students via the Canvas Dropbox tool. **An electronic copy of each commented report also must be submitted as part of end-of-semester reporting.**

Learning to Grade Lab Reports

One of our highest priorities is ensuring that GTAs grade students fairly, giving similar scores for work of similar quality. We also want to ensure that students get actionable feedback that helps them grow as writers. Finally, we want GTAs to spend their grading time efficiently. To those ends, we have 3 training activities for GTAs.

1. Annotating text excerpts. This is the same activity that students do. GTAs do it to learn what questions their students might have, what data the annotation activity provides, and how to adjust the general writing workshop to address student misconceptions.
2. Marking up previously graded reports. Before grading the first time, GTAs are given a set of training reports and asked to grade them using our bins-based scoring. After grading, GTAs will discuss their scores and comments with experienced graders during a lab prep meeting.
3. Round-robin scoring. GTAs select 4 reports from the first set of the semester, score them, then pass the 4 reports to another GTA who also scores them. Scores and discrepancies are discussed in the next lab prep meeting.

Report Grading Process

Criteria

These are the criteria we use to assign scores to lab reports. They can be divided into **basic criteria, technical flaws**, and **writing quality flaws**.

Basic Criteria
1. Contain hypothesis, clearly articulated research goals.
2. Clearly organized. Sections reflect structure of a scientific paper.
3. Data are clear, informative; summarized in figures, tables.
4. Report interprets results. Discussion states if hypothesis supported, why.
5. Supporting 1° literature backs Intro, Discussion

Technical Flaws
1. Reporting raw data
2. Several errors in data summaries (graphs, tables)
3. Improper statistics
4. Claims not supported by evidence provided, cited
5. Unclear connection b/w claims, evidence, reasoning
6. Citation errors or misuse
7. No references to figures, tables

Writing Quality
1. Unclear wording
2. Poor flow
3. Lacks clear thought process, plan connecting parts
4. Imprecise language
5. Wordy, not concise
6. Not technically presented; "emotional" language
7. Distracting elements detract from clearly understanding outcomes.

There are five pre-defined Basic Criteria; either a student's report meets them, or it does not. Items listed under Technical Flaws or Writing Quality Flaws are **examples** of the most commonly encountered errors; there could be other flaws.

General Strategy

Most students in BioCore have not read scientific primary literature before, and very few have designed experiments or written reports in our format.

Grading and comments should focus on **guiding and helping students improve as writers (coaching)**. From WAC/WID literature we know students improve more and faster if we:

- **Limit the number of comments**. Students only process and respond to a limited number of feedback items. Given too many comments, students tend to correct simple issues first and leave larger issues uncorrected.
- **Focus on the largest problems first.** Work down to smaller errors later. This reinforces the previous item and is more likely to improve their score.
- **Refer students to resources**. We provide extensive guidelines. Students need to develop a habit of seeking out their own answers instead of looking to us for them. This also reduces the amount of time spent writing the same comments over and over.
- **Do not copy-edit unless absolutely necessary**. It is appropriate to point out where writing is vague or unclear, but not every instance. Students must learn to self-correct rather than expect someone will show them what to do every time.
- **Ask questions that encourage reflection**. "Reflective coaching" models the kinds of questions students should ask themselves. With practice, students will adopt these questions and begin to self-correct.

Workflow

This is one way to organize the grading process your first few times. As you gain experience, you may find other ways that work better. That is fine; consistency is more important than how you get there.

- **Allocate 10-15 minutes per report.** Keep a timer on hand; your phone works well. If you fall behind, decide whether you are tired and should take a break, or are spending too long on each report.
- **Budget your time appropriately.** Occasionally a report needs so much work that a face to face meeting with the student to discuss the problems will take less time than writing out comments. When this is the case, stop and schedule a meeting.

First Pass: Initial Sorting

Open each report in MS Word and **SKIM** it (1 minute or less), looking for the features in the table below. When you see one, highlight it and attach a comment box (you will fill it in during the next step.) Sort reports into 3 provisional groups.

- Clearly unacceptable. One or more basic criteria are obviously missing.
- See some flaws.
- No obvious flaws.

Feature	Interpretation/Group
Are all required **sections** there?	"No" on ANY item means report goes into "Unacceptable" group
Do you see **citations** in Introduction AND Discussion? Look for [Name: Year] format	
Quickly read last 1-3 lines of Introduction. Is there a **hypothesis** near end of Introduction?	
Is there **a table or figure** summarizing data?	
Quickly skim first **1-3 lines of Discussion**. Does author reference their hypothesis?	"No" should go into "Some flaws" group – could be elsewhere
Does the **flow and wording** sound reasonable for a technical audience	"No" should go into "Some Flaws" group
Do **figures or data tables** at end look right? Do **citations** at the end look generally right?	Present, but you see errors means report goes in "Some flaws" group.
Nothing stands out in first brief skim through	Put in "No obvious flaws" group

Second Pass: Double-Check & Read Deeper

This time don't grade one entire group at once. Take a report from each group in turn.

- This helps you avoid getting frustrated when grading.
- You are more likely to subconsciously change your grading standards if you keep grading reports of similar quality.
- Remember that your first pass was an initial sort only. If you re-read a report an see that you sorted it incorrectly, move it into a different group.

This time you read the full text of each report. You have three goals this time.

1. You already marked several items with comment boxes. This time you should confirm that they are actually present/ flawed/ absent.
2. Identify the 2-3 highest impact corrections that the student needs to make. These are what you will point out in your reflective coaching comments. Put your coaching comments on the first page of the report, with the student's overall score. Remember, these comments should directly reference the criteria.
3. Identify and provide short comment on other errors. Limit these to 3-5 per page. Avoid simple copy-editing. As often as possible, address these errors by:
    - Asking reflective coaching questions, or
    - Referring students to the Resource Guide or other reference sources.

Strategies for marking up a report from each group.

- Unacceptable Group:
    - If one of the 5 basic criteria) is indeed missing, leave the report in this group.
    - Identify all of the essential items that the student does not have.
    - In the front page comment, **list which required items are missing, and the score, then stop.**
    - You are not required to provide any further comments. A report that does not meet basic criteria should take LESS time to grade, not more.

- Some Flaws Group:
  - As you read, separate reports into 3 sub-groups:
    - Flaws in **writing** only
    - Flaws in **technical** execution of stats, figures, tables, etc.
    - Flaws in **BOTH** areas.
  - As you divide the reports, look for the larger/global errors the student should address first. What 2-3 corrections that the student could make that would make the report fundamentally better?
  - In the front page comment, summarize the most important corrections needed, and the score.
  - Add no more than 3-5 short comments per page. Use these comments to point out smaller corrections, not the global issues. Comments should be questions or refer to other sources if at all possible.
- No Obvious Flaws Group:
  - Double check that you did not overlook any writing or technical flaws.
  - Identify 2-3 points where you think the report could be improved.
  - In the front page comment, summarize the most important areas the student could improve, and the score.
  - Add no more than 3-5 short comments per page. Use these comments to point out smaller corrections, not the global issues. Comments should be questions or refer to other sources if at all possible.
  - As the grader, remember that even if a report earns the highest possible score, it can always be better.

Provide Most of Your Feedback As Reflective Coaching, Not Copy Editing

Reflective coaching comments have both specific information or guidance/rationale, and foster thinking. Often they have open ended questions that help a student think about BOTH WHAT TO CHANGE AND WHY. This approach is harder for students at first, but with practice students learn to self-correct the indicated error and apply similar thinking to other situations.

This is an example a **front-page summary comment** for a lab report. The following table breaks down the individual elements.

> *This is good work on your first submission. You met all 5 of our basic criteria. The most important area to work on next is your discussion. Really think about resource allocation and herbivory, and your explanation. Ask yourself, is there another possible explanation besides herbivory? Also think about your results and what they're really saying. Is there a better way to display or summarize the data that makes your main points clearer? Your writing was very clear; good work! There were some other minor technical points that also need correcting that I've highlighted.* ***Overall Assessment: Needs Minor Revisions.***

Statements	Breakdown
The most important area to work on next is your discussion. Also think about your results and what they're really saying.	These two statements identify the first 2 points where the student should concentrate effort.
Really think about resource allocation and herbivory, and your explanation. Ask yourself, is there another possible explanation besides herbivory?	Student is prompted to think more about their initial explanation, and whether it is the only option. Note that the comment does not actually give alternatives, only points to a possibility.
Is there a better way to display or summarize the data that makes your main points clearer?	The question should be self-evident; there likely is a better option. The student can either look for a solution themselves, or talk with the instructor.
Your writing was very clear; good work!	Student does not need to focus on improving writing at this time.
There were some other minor technical points that also need correcting that I've highlighted.	Technical errors (statistics, figures) are the third major area needing correction.
Overall Assessment: Needs Minor Revisions.	Score aligns with description; report needs work mainly on interpretation of data, other smaller technical aspects.

Provide Shorter Reflective Comments In Text

The excerpt below from a student report has two comments for the **same** block of text. The first version is in the format of a simple correction. The second version invites deeper thinking.

…been chosen as the model organism for this experiment due to their easily identifiable aggressive behaviors. Specifically, we will be testing how the aggression of betta fish alters when they are exposed to different living environments: clear water and murky water. Male betta fish identify their opponents visually through unpatterned bodies and long fins [Tillberg: 2010], so if they are less able to identify one another then it is less likely that they would engage in aggressive behaviors. We hypothesize that the betta fish in the clear water will be more aggressive.

A Daniel Johnson
Correction:
Not clear. Need to say something like "murky water limits males' ability to see the triggering stimulus."

A Daniel Johnson
Reflective short comment:
Why is this a relevant stimulus?

These are other examples of shorter reflective comments like you might add to report pages. Read each comment. Try to identify the specific information or guidance/rationale, and how each comment encourages deeper thought.

- Did you mean for each leg before and after injection? Why is that important?
- What is the relevance of this observation in the moth life cycle?
- Are you sure it is the correct tense for this section? Check it in other primary lit.
- Did you find any primary literature articles that deal with interspecific interactions in betta fish? It would be very useful to cite and talk about those here, if there are.

Remember, you want to limit your in-text comments to 3-5 per page, & focus on basic criteria first, then the large global issues. Move to smaller details after the student has corrected basic criteria and global problems.

Limit the Number of Simple Copy-Editing Comments

Copy-editing comments explain how to correct a SPECIFIC location but give no rationale. They range from pointers (simple punctuation marks or single words indicating an error) to more specific instructions. They do not invite reflection or guide broader thinking, so any lessons learned do not transfer easily to other situations.

Below are examples of copy-editing comments, and how they could be modified to foster reflection. Several reflective versions (marked **) can be recycled with little or no revision and used in multiple situations.

Correction-Oriented Comment	More Reflective Alternative
?? (Can be interpreted many ways)	What is the purpose of this statement?**
Correct this scientific name, i.e., italicize or underline.	Is this correct format?**
No direct quotes – paraphrase	Are quotes allowed? How can this be presented more succinctly?**
Capital "P" here	What is standard format for reporting stats?**
Refer to Figure 1/Table 1 here.	Where are your references to each figure or table?**
Add/revise/remove a word, phrase, image, etc.	Add/revise/remove a word, phrase, image, etc., because …
Ambiguous, awkward	I am not sure what this sentence means. Are you referring to X, or Y?
Methods should be past tense	Check articles we read previously for correct tense, format for this section.**
Raw data	Looks like raw data; where are these summarized?
Avoid recipe style (with no further explanation)	Check articles we read for correct tense, format for this section.
Need units	What is required for all numbers? Is this correct format?**
Organize this section more clearly. Put X, then Y, then Z.	I'm not following your logic. Do you mean…?**
Clarify this step in procedure or analysis	I am not sure what this means. Do you mean X, or Y? Could someone with prior knowledge of this lab repeat what you did?**
Be more specific about how salinity changes root transport.	Focus in here. How so? What biological processes are happening due to salinity?**
I'm having trouble following logic here. Make sure your hypothesis is consistent with the rest of your introduction	I'm having trouble following your logic here. How could you revise the early part of the Intro so it leads to your hypothesis?
State here why plants allocate resources to leaves versus roots.	Be more specific. Why would they allocate resources to either structure?
Revise "changes over time" to say "changes in root growth per unit time."	What does phrase "changes over time" mean? Root growth? Shoot growth? Something else?
No. Carbon allocation explains this more than any other nutrient.	What about carbon? Is R:S ratio showing carbon allocation more than other nutrients?

Referencing BioCore Resource Guide in Comments

Our Resource Guide is very thorough, but students are notoriously reluctant to use it. Reinforce that your students should be referring to the Resource Guide FIRST by referring to specific pages in the Guide (especially for basic formatting and technical errors) instead of writing out your own detailed explanation or feedback comment. This also cuts down grading time.

Correction-Oriented Comment	Alternative Using a Resource Reference
Report the stats in your results using (t=, d.f. =, P=) format	See p. 48 of Resource Guide for how to report your stats results
Add your alpha value	
Report mean as x±s.d.	
Improper citation format. Use [Name: Year] in text.	Follow p. 36 of Resource Guide for in-text and end citation format.
This citation is not correct. We do not use URLs or DOIs only. You need to include authors, year, title, journal info.	
You need y-axis labels for this figure. Add a caption with an explanation of the measurements. Put caption in Figure Legends section.	See p. 41 of Resource Guide for format of axis labels, contents and location of caption.

Tips*:*

- *If you find you are putting the same comment on different reports, create a master list of comments and copy/paste the appropriate ones rather than re-typing them.*
- *If you are an experienced GTA, remember that the Resource Guide is updated regularly. Double-check that you are using the correct page numbers for the current version.*

If You MUST Address Basic Writing Mechanics

Sometimes basic writing is the biggest weakness of a lab report. Here is an example; this Introduction is so poorly written that it is hard to understand the student's thinking:

> Organisms metabolism is fundamental in the ways that it is the sum of the chemical reactions that take place within each cell of a living organism that provide energy for vital processes and for synthesizing new organic material. The amount of energy expended by an animal over a specific period of time is referred to as a rate of heat energy released from an animal's body (this procedure is known as calorimetry). However, measuring heat from an animal body with accurate precision requiring special equipment, which is often expensive. So, we measure rate that is controlled directly with heat production by oxygen consumption.
>
> In an article published in 2000, K.A. Sloman set to exploring environmental factors and specific metabolic rate. The researcher carried out a study where he observed the effects of aggression on metabolism through the use of the brown trout (salmo trutta). Sloman placed a pair of the species in small, confined aquarium where he allowed one trout to establish a social hierarchy by becoming the dominant fish. He found that, other fish (subordinates) experienced high levles of soceity stress as a result of the aggression exhibited by the dominering trout. This led the smaller fish to have an increase in specific metabolic rate, which was measured through oxygen consumption (Sloman AK, 2000. Annals Biol. 34:15-17). This experiment is similar to our own as we wish to test the effects of aggression on the specific metabolic rate. In order to do this, we will use crayfish (orconectes sp.). We will carry out this experiment with the following hypothesis in mind: a crayfish is exposed to aggression/social stress should have a significant increase in specific metabolic rate.

It is hard to address so many errors using just reflective coaching and references to other resources. Adding to the challenge, the entire report likely needs corrections, not just 1-2 paragraphs. We do not expect GTAs to spend time copy editing entire reports. Instead, use one of these two strategies for responding to writing mechanics problems.

- **Option 1:** highlight one poorly written paragraph, and attach a new comment. List the specific errors that you see. Be sure to tell the student that you saw similar errors in other paragraphs, and that they are responsible for finding and correcting them. For example, the feedback comment for the flawed paragraph above might read:

  You have a lot of basic writing flaws in your report that you need to correct or revise. For example, I found all of these basic errors in just these two paragraphs:
    - Unclear flow of the logic in both paragraphs
    - Errors in grammar (example: "Organisms metabolism is fundamental in the ways that it is the sum..."
    - Awkward wording, run-on sentences (ex. "The amount of energy expended by an animal over a specific period of time is referred to as a rate of heat energy released from an animal's body (this procedure is known as calorimetry)."
    - Improper word usage (ex. dominant, not domineering)
    - Improper citation location and format (look at Sloman reference.)
    - Format errors in scientific names
    - Spelling errors (ex. levles of soceity)

  You need to revise this report very carefully. I recommend that you contact the Writing Center in the library first. They can help you with basic writing issues. After meeting with their tutors, make an appointment with me to work on how you could better organize your logic and key points.

- **Option 2:** use minimal marking. Edit one paragraph thoroughly for grammatical errors. Then attach a comment in the margin telling the student they are responsible for fixing similar errors beyond this paragraph. To learn more about minimal marking, go to: www.csuchico.edu/ge/faculty/writing_intensive_u/responding_to_writing/responding_to_surface_errors.shtml

Other General Suggestions When Giving Feedback

- Provide some positive encouragement or praise when warranted, but do not over-state it, or give undeserved praise.
- If one particular item was done well, refer the student to it as an example of how to correct other parts of the report.
- Avoid "but." Think about this comment: "I like how you wrote your Intro, but the Methods need…". The "but" negates what the student did well. Try wording that invites continued effort: "I like how you organized your Introduction. For the revision, try using the same organizational strategy for your Methods section, which needs…".
- Do not interject writing conventions and idioms of your sub-field. For example, students are not required to use different formats for in-text citations, depending on the number of authors on the source article. These details become important later as students specialize; at the introductory level we want to focus on foundational issues.

Recording Report Scores in Canvas

Be sure your students understand that these numbers represent categories, not grades.

- 4 = Acceptable. Translates to an “A”/95%.
- 3 = Needs minor revisions. Translates to a “B”/85%.
- 2 = Needs major revisions. Translates to a “C”/75%.
- 1 = Submitted but Unacceptable. Translates to a high “F”/55%.
- No report submitted, or plagiarized. Translates to a zero.

We expect reports to be graded and returned to students within 7 calendar days, meaning by the next lab meeting.