Determining the Trade-off Between Plant Growth and Defense for Brassica Rapa

Anika Ramachandran,[1] Julie A. Herman[2]

[1]Science Internship Program (SIP-UCSC)

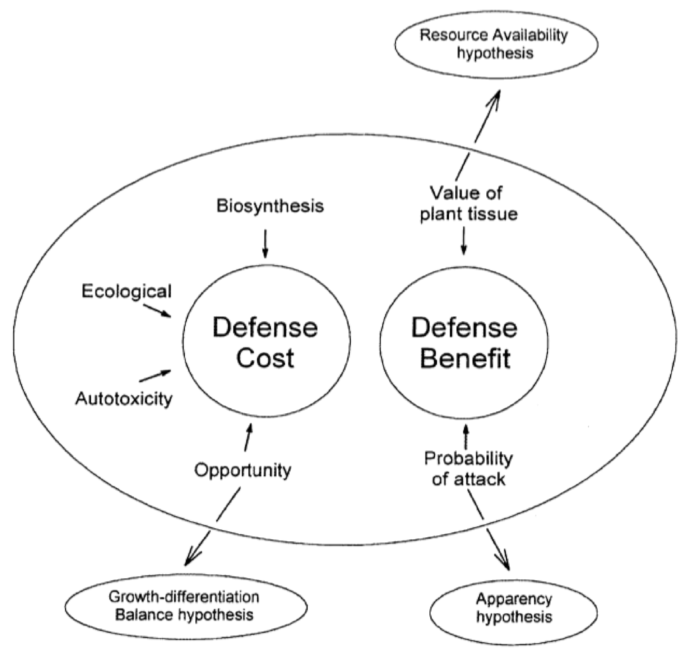
[2]University of California, Santa Cruz

SIP SCIENCE INTERNSHIP PROGRAM

Introduction

Plants are essential components of ecosystems on Earth. However, plants can't move to ward off attack, so instead they have developed sophisticated physical and chemical mechanisms to defend themselves from any attack.

Defense mechanisms have long been of interest to biologists, who have tried to understand and predict the genotypic, phenotypic and geographic resource variations as the delicate balance between plant growth and defense. While we are still far from developing a single, unified theory of plant defense, several promising models and hypothesis have been proposed (and some debunked) to explain existence and mechanism of trade-off between plant growth and defense.



Optimal Defense Hypothesis

Figure 1 Demonstrates the various facets of the Optimal Defense Hypothesis as an example of the complexity in finding a model that explains the balance between plant growth and defense.

Adapted from Hamilton et al. 2001

The Optimal defense hypothesis focused on genotypic variation with emphasis on the cost of defense. The Carbon/Nutrient Balance (CNB) hypothesis further tried to explain phenotypic variation in secondary metabolism with a premise that moderate nutrient deficiency limits growth more than photosynthesis. The Growth-Differentiation Balance Hypothesis generalizes this further by explaining the trade-off between growth and defense, and predicts that competition and herbivory are the dominant forces that affect the fitness of plants and that fast-growing plants have lower levels of defense than inherently.

The theories often differ on how resource-levels affect how mush a plant can and does allocate to defense at times of danger and peace. While several experiments have tried to test these hypothesis, they have been too focused on a single hypothesis or failed. Our goal is to test these theories by directly manipulating nutrients, water availability, and herbivory environment.

Hypotheses

- Plants with higher amount of nutrients and water will not experience tradeoffs in growth and defense.
- Cutting and jasmonic acid, both forms of "threat" to the plant, will induce similar defense mechanisms at the cost of reduced growth.
- The plants without the Jasmonic Acid and Cutting inductions will allocate majority of their resources to growth as defense does not take the foremost attention.

Procedure

1. Label 12 plant cones for each of the12 groups according to table.
2. Add regular soil to low nutrient treatment groups and soil with into each tube of the high Nutrient treatments
3. Place the tubes with soil into floral foam pieces in a specified random arrangement.

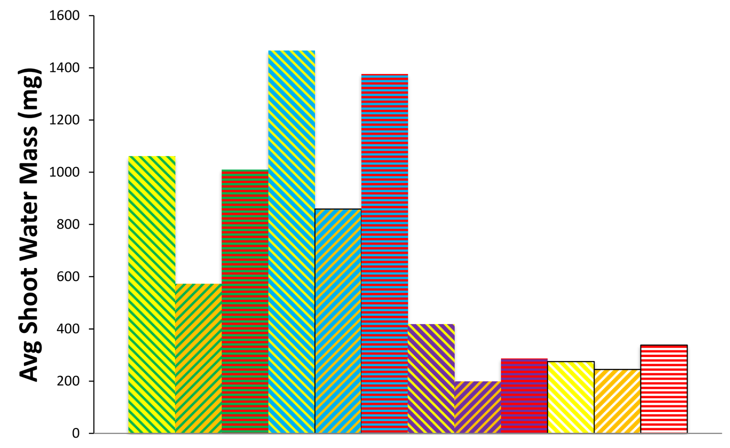
	Inductions		
	Control	JA	Cutting
NUT/WAT	1	2	3
NUT/wat	4	5	6
nut/WAT	7	8	9
nut/wat	10	11	12

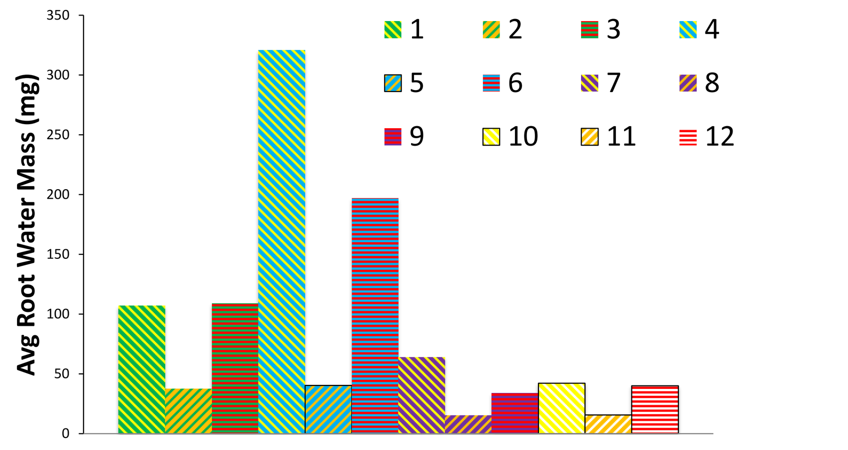
Table 1 Treatments and numbering. NUT and WAT means high nutrient and water content; nut and wat mean low content.

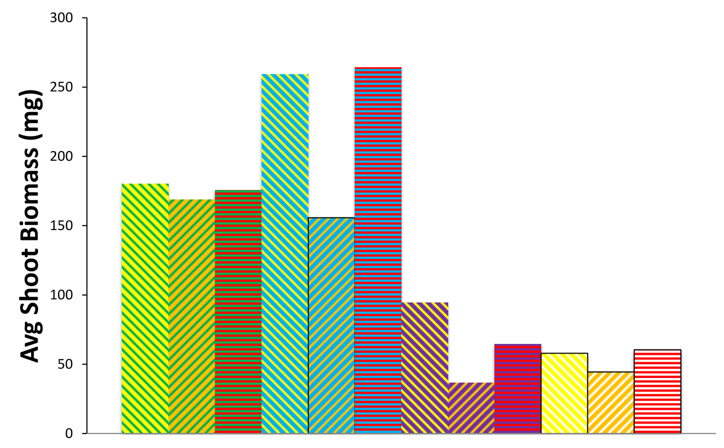
4. For low water treatment, push the tube 4 inches into the floral foam. For high, 7 inches.
5. Next day, add more water to the trays to maintain 2 cm line.
6. Sow a seed into each plant cone. If the plants are under high nutrient treatment, also add 3 fertilizer pellets.
7. Transport all the plants into a growth chamber for a regulated environment.
8. For the first 3 days of planting squirt the plants with DI water, several times daily.
9. Record the planting and germination date of each plant (should occur day 1 to 3)
10. While the plants are in their growth stage, record the following characteristics of the plants on its odd age days (day of germination being age 0 for that plant): height (of stem), number of new leaves (keep track with paint), branch count and flower count. Every day record the stage of the plant (ex. growing, budding, flowering).
11. NOTE: If a plant does not germinate after 6-7 days of planting or dies due to unnatural circumstances (ex. stem snaps while working with it), replanting may be necessary.

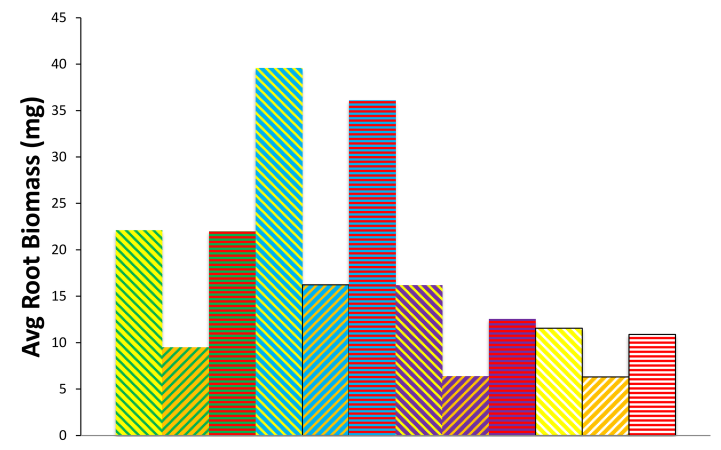
12. Recording new planting date, proceed again to grow plant from step 8
13. On day 5 or so, after most plants have germinated, commence the Inductions (None, Jasmonic Acid, Cutting) for 3 days every week. Induce all plants that have germinated by that day of induction. Place 5 microL of a 7.5mM Jasmonic Acid in 0.8% Ethanol Water solution on each leaf of every plant under a jasmonic acid treatment. For the other plants, simply place 5 microL of a 0.8% Ethanol Water Solution. For the plants with the cutting treatment, make one cut on each leaf.
14. When the plant is 18-20 days old, remove it from the floral foam for harvesting. For each of the 12 treatments, 3-4 of the plants under that treatment will have the leaves and soil of the plant frozen for later analysis. The rest will have the roots and shoots separated and weighed before and after they are dried.
15. Crush the plant soil and leaf samples that were frozen into homogenous powder. Place 2-5 g into a tin foil for elemental analysis using mass spectroscopy.

Preliminary Data



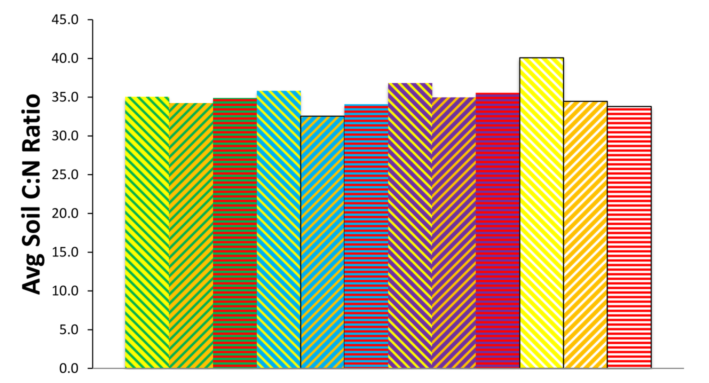


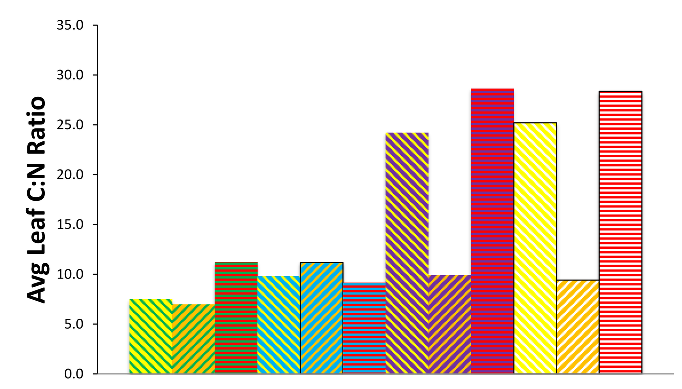




Take-Aways:

- The amount of water retention and plant mass seems highest particularly in treatments with the high nutrient low water resource allocation, followed by high nutrient and water.
- In every set of 3 attributed to different resource levels, the ones induced with Jasmonic Acid have the lowest water retention and plant mass.
- Lower C:N Ratio in the leaves implies that the plants induced with Jasmonic Acid are producing more chemical defenses





Future directions

- The defense metabolites will be quantified to analyze alongside the growth and resource allocation data.
- The rate of growth of the plants can also be analyzed to see plants adaptation times to attack.

Acknowledgments

This research was made possible by the SIP program, the Kay lab, contributions of SIP student Jocelyn Banuelos and the UCSC Greenhouse staff (Molly Dillingham and Jim Velzy).

References

Boughton, A.J., Hoover, K. & Felton, G.W. J Chem Ecol "Methyl Jasmonate Application Induces Increased Densities of Glandular Trichomes on Tomato, Lycopersicon esculentum " (2005) 31: 2211. doi:10.1007/s10886-005-6228-7 Springer Link. Web. 21 Nov. 2016.

Hahn, Philip G., and John L. Maron. "A Framework for Predicting Intraspecific Variation in Plant Defense." Trends in Ecology & Evolution 31.8 (2016): 646-56. Trends in Ecology and Evolution. Web. 21 Nov. 2016.

Hamilton, J.g., A.r. Zangerl, E.h. Delucia, and M.r. Berenbaum. "The Carbon-nutrient Balance Hypothesis: Its Rise and Fall." Ecology Letters 4.1 (2001): 86-95. ResearchGate. Web. 21 Nov. 2016.

Harms, Karsten, Rainer Atzorn, Alan Brash, Hartmut Kuhn, Claus Wasternack, Lothar Willmitzer, and Hugo Pena-Cortes. "Expression of a Flax Allene Oxide Synthase CDNA Leads to Increased Endogenous Jasmonic Acid (JA) Levels in Transgenic Potato Plants but Not to a Corresponding Activation of JA-Responding Genes." American Society of Plant Physiologists 7.10 (1995): n. pag. The Plant Cell. Web. 21 Nov. 2016.

Herms, Daniel A., and William J. Mattson. "The Dilemma of Plants: To Grow or Defend." The Quarterly Review of Biology, vol. 67, no. 3, 1992, pp. 283–335. www.jstor.org/stable/2830650. Web. 21 Nov. 2016.

H Gundlach, M J Müller, T M Kutchan, and M H Zenk "Jasmonic acid is a signal transducer in elicitor-induced plant cell cultures" PNAS 1992 89 (6) 2389-2393 Proceedings of the National Academy of Sciences of the United States of America Web. 21 Nov. 2016.

Kazemi-Dinan, A., Barwinski, A., Stein, R.J., Krämer, U. and Müller, C. (2015), "Metal ppl, 157: 3–10. doi:10.1111/eea.12333 Wiley Online Library. Web. 21 Nov. 2016

Kunkel B N, Brooks D M. 2002. "Cross talk between signaling pathways in pathogen defense."Current Opinion in Plant Biology 5:325–331. Web. 21 Nov. 2016.

Maschinski J, Whitham T G. 1989. "The continuum of plant responses to herbivory: the influence of plant association, nutrient availability, and timing." American Naturalist 134:1–19. Web. 21 Nov. 2016.

Rosa Lozano-Durán, Cyril Zipfel, "Trade-off between growth and immunity: role of brassinosteroids", Trends in Plant Science, Volume 20, Issue 1, January 2015, Pages 12-19, ISSN 1360-1385, http://dx.doi.org/10.1016/j.tplants.2014.09.003. Trends in PlantScience. Web. 21 Nov. 2016.

Salmon slammer. "Re: More on Jasmonate Usage." Blog comment. The Farmer. Cannabis Cultivation Network, Apr. 2012. Web. 21 Nov. 2016.

Schmelz, E.A., Alborn, H.T., Banchio, E. et al. Planta "Quantitative relationships between induced jasmonic acid levels and volatile emission in Zea mays during Spodoptera exigua herbivory " (2003) 216: 665. doi:10.1007/s00425-002-0898-y Web. 21 Nov. 2016.

Simms E L. 1992. "Costs of plant resistance to herbivory". Pages 392–425 in Plant Resistance to Herbivores and Pathogens: Ecology, Evolution, and Genetics, edited by R S Fritz and E L Simms. Chicago (IL): University of Chicago Press. Web. 21 Nov. 2016.

Stamp, Nancy. "Out Of The Quagmire Of Plant Defense Hypotheses." The Quarterly Review of Biology 78.1 (2003): 23-55. PubMed.gov. Web. 21 Nov. 2016.

Thaler, Jennifer S. "Jasmonate-inducible Plant Defences Cause Increased Parasitism of Herbivores." Nature 399 (1999): n. pag. Nature. Web. 21 Nov. 2016.

Wilkens R T. 1997. Limitations of evaluating the growth-differentiation balance hypothesis with only two levels of light and water. Ecoscience 4:319–326. Web. 21 Nov. 2016.