Triggers for *Acacia koa* Development: A Function of Time or Size? The Role of Microclimate and Implications for Management

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Introduction

Koa occupies a dominant position in a wide range of Hawai`ian forests on windward (top left) and leeward (top right) Big Island from near sea level to over 2100 masl and in forests receiving 800 - 6000 mm rainfall annually. Following extensive deforestation for pasture and agriculture (Gon et al 2006), koa has been planted for watershed restoration (Woodcock 2003), habitat restoration (Jeffery and Horiuchi 2003), and industrial wood production (Scowcroft et al 2010), nearly all of which have been planted as single-aged monocultures. These can lead to fast growth (Earnshaw et al 2016, submitted) and, often, poor stem form (Scowcroft et al 2010).

Koa, a shade-intolerant species, might benefit from alternative plantation designs, but tests on koa morphology in response to light availabiltiy are non-existent. Importantly, early growth in koa is associated with a change in leaf form from juvenile true leaves to phyllodes (see photo, left).

True leaves are bipinnate, horizontally-oriented, performed better in shaded conditions, and cost less to produce than phyllodes, which are vertically oriented and adapted to drought (Walters and Bartholomew 1984; Pasquet-Kok et al 2010).

In spite of genetic variation in the timing of transition for koa (Daehler et al 1999) and evidence in other acacias that populations from arid environments transition faster (Atkin et al 1998), light quantity and quality can effect the timing of transition and seedling morphology (Forster and Bonser 2009), the triggers for developmental shifts and their effect on future morphology have not yet been fully elucidated.

For this reason, we conducted a study in 2013 to ask the following questions:

1. Is the timing of transition in koa a function of time or size (ontogeny)?

2. How do light and light quality interact to affect the timing of transition and the resulting phenotype?

3. Is development plastic in response to water availability?

4. Do populations from contrasting environments differ in response to light and water availabliity?

Methods

Design:

The experimental design was split-plot with LIGHT as the whole plot factor and WATER as the subplot factor. There were three replicates. Representative bulked seeds from Honomolino (leeward, dry side) and Umikoa (windward, mesic side) were used to test contrasting ecotypes.

Light treatments: FULL (100% sunlight, 1.49 R:FR), 70FILM (70% sunlight, 1.28 R:FR), 25FILM (25% sunlight, 0.68 R:FR), 25CLOTH (25% sunlight, 1.48 R:FR). See below for photo.

Water availability treatments: SATURATED (well-watered, daily), STRESSED (VWC allowed to drop to 60% field capacity before each watering event)

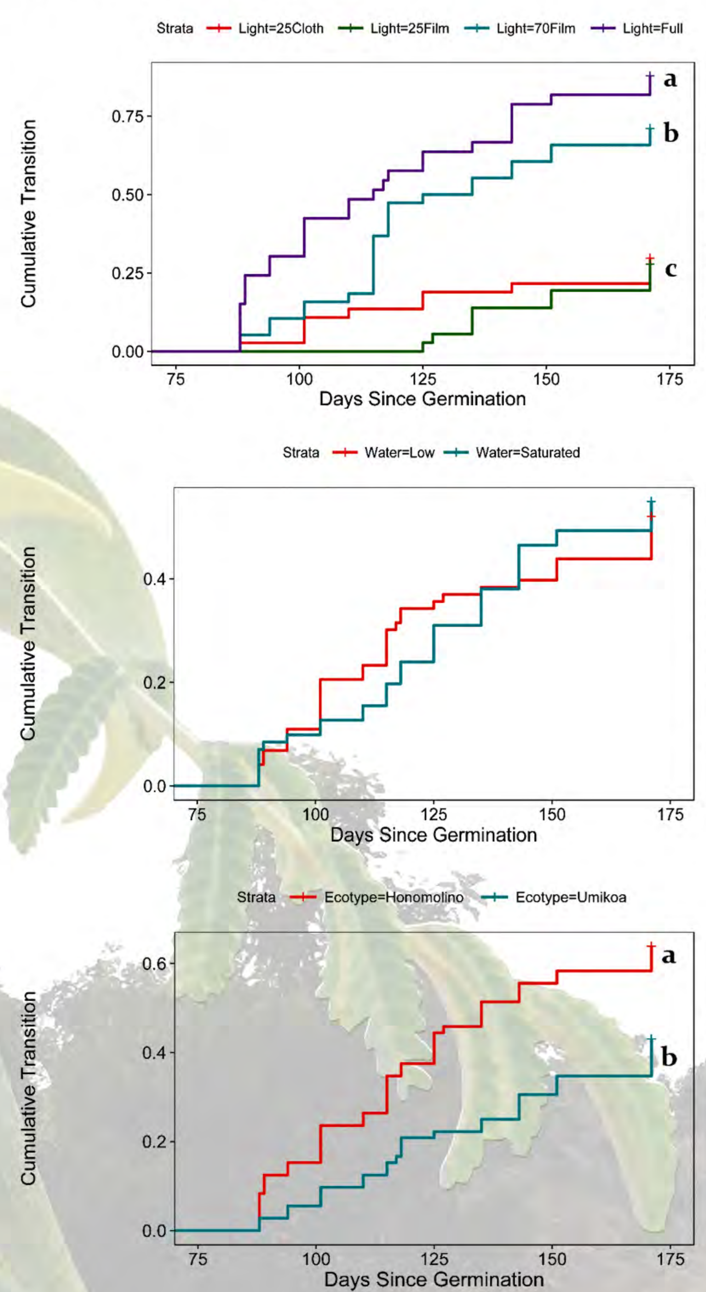
Schedule: The study lasted 171 days following germination of the seedlings, at which point they outgrew the greenhouse. Not all of the seedlings had transitioned to phyllodes.

Measurements: After possessing at least one fully developed phyllode, the seedling was harvested and morphological traits were measured, such as height, root collar diameter, number of nodes, number of nodes to transition, number of branches, height to first branch, and diameter of first branch. Seedlings were then separated in above-ground stems, roots, and leaves, before being dried at 70 degrees C and weighed. Allocation ratios were then calculated: Stem Mass Ratio (SMR; (stem):(roots + leaves)), Leaf Mass Ratio (LMR; (leaves):(roots + stem)), and Root Mass Ratio (RMR; (roots):(stem + leaves)).

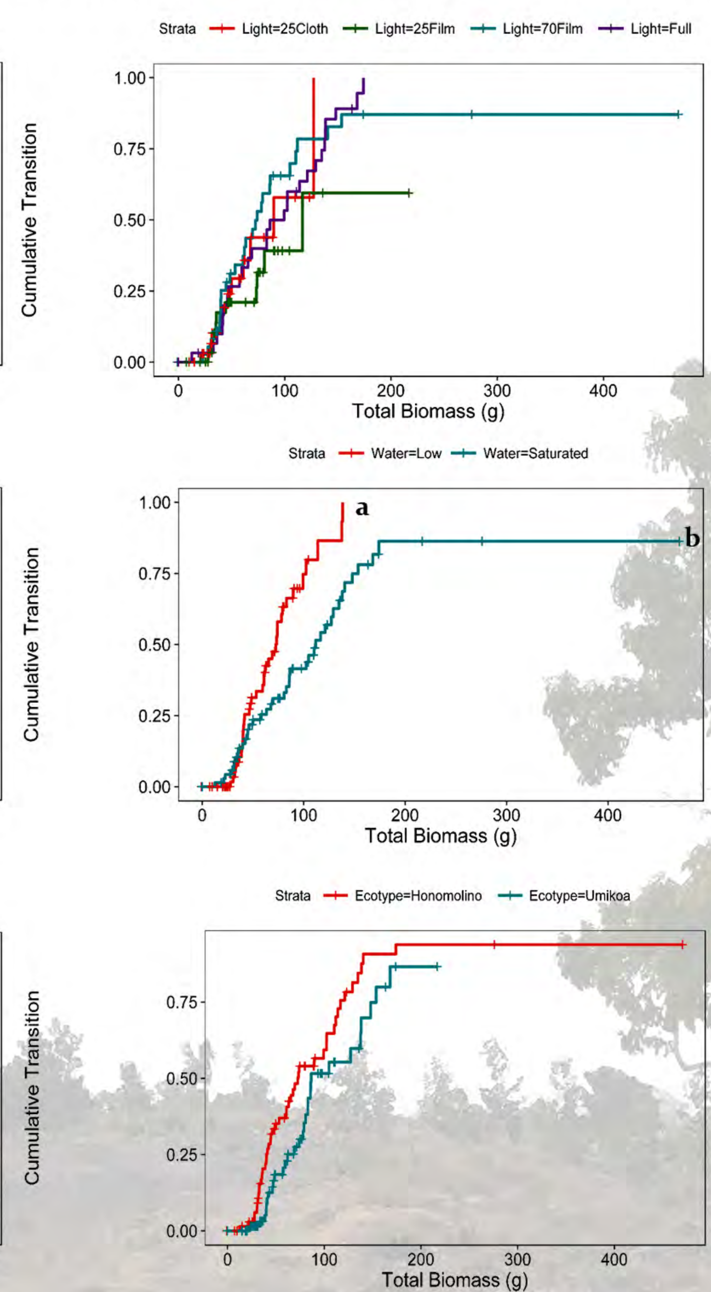
Analyses: the probability of transition over time and ontogeny (eg. nodes, total biomass) was tested using Cox proportional hazards models in R as a function of LIGHT, WATER, and ECOTYPE. Results were plotted as Kaplan-Meier curves. Relative performance of time versus ontogenetic models were measured using AIC. Preliminary results for phenotype and effect of light quality were plotted as linear regressions.

Results and Discussion

TIME: AIC = 661.8175

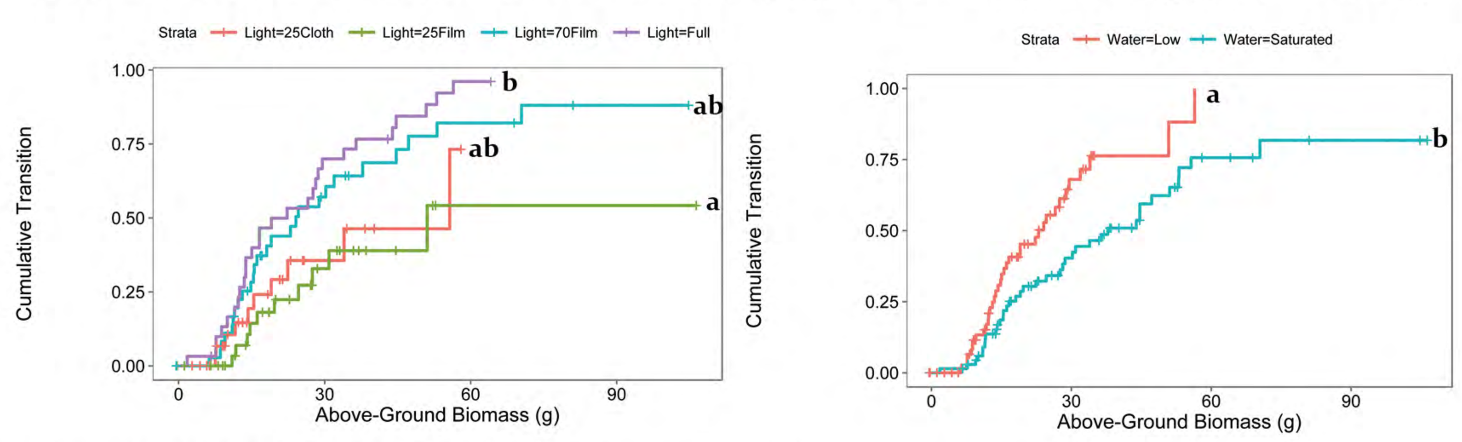


SIZE (TOTAL BIOMASS): AIC = 591.412

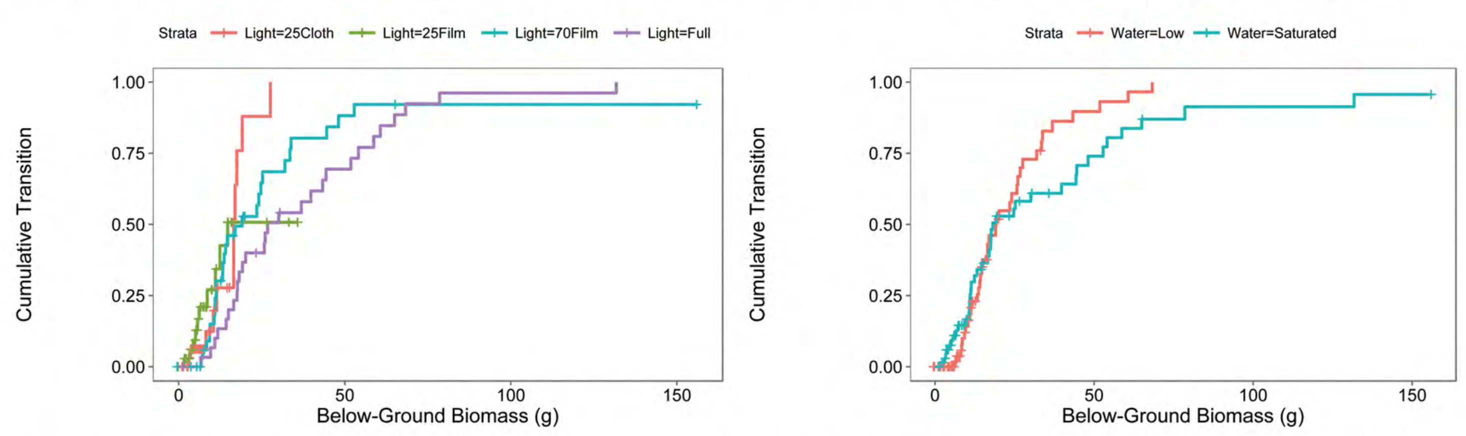


If we focus on time, LIGHT is the driving trigger of transition to phyllodes, but from the plants perspective LIGHT may be irrelevant if environment is held constant, as WATER is the driving trigger when we measure change over the course of TOTAL BIOMASS accumulation. What if we separate TOTAL BIOMASS into ABOVE-GROUND, BELOW-GROUND, and LEAF BIOMASS?

ABOVE-GROUND BIOMASS (AIC = 579.1446, ECOTYPE (P = 0.0057, not shown)

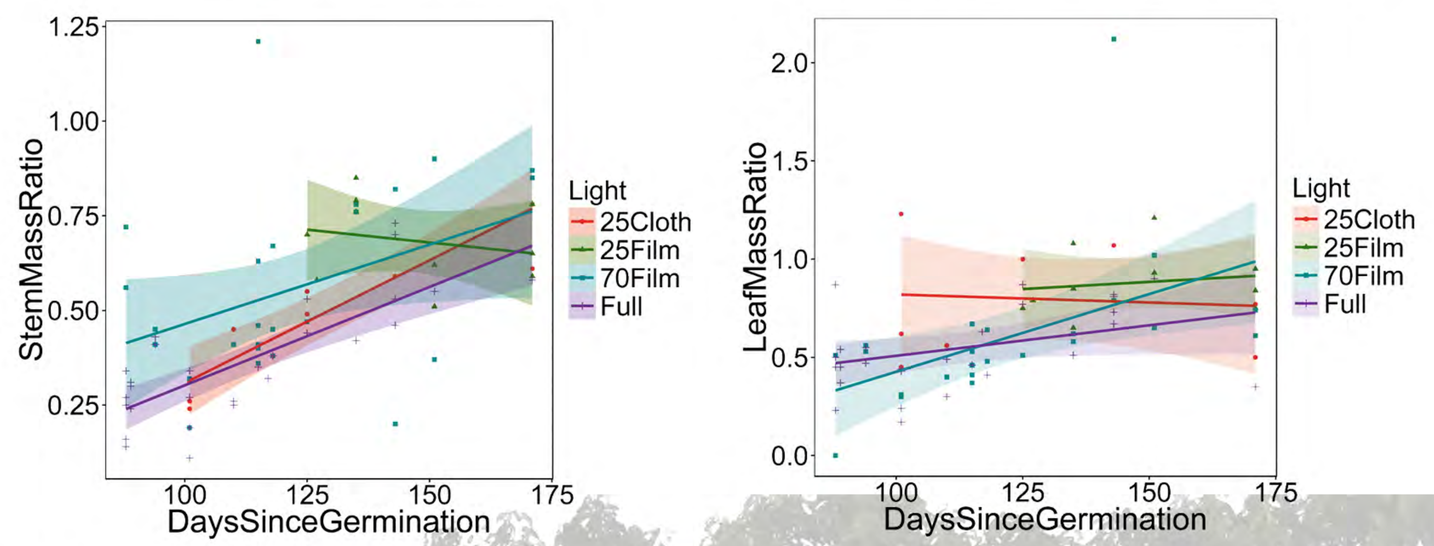


BELOW-GROUND BIOMASS (AIC = 560.2518)
LIGHT (chi-sq P = 0.1317), WATER (P = 0.2853), ECOTYPE (P = 0.8161, not shown)



Although LIGHT and WATER trigger transition when looking at ABOVE-GROUND BIOMASS and none of these main effects appeared to trigger transition when looking at BELOW-GROUND BIOMASS, the latter model performs better overall.

This study presents strong evidence for LIGHT, WATER, and ECOTYPE as contributors to the rate of transition. Preliminary data also suggests that the rate of transition affects the phenotype and that this phenotype is driven to some extent by variation in R:FR. These results suggest the need to test alternative plantation designs, which has led to two field studies currently underway in



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Citations and Credits

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