Yield in agricultural fields is influenced by the shape of developmental growth curves (Figure 1). Developmental variation can have dramatic effects on plant fitness and yield, and it is, consequently, an important target for natural and artificial selection by crop breeders. Characterizing genetic controls and environmental dependencies of organismal development may lead to better predictions of yield. Further, describing the shape of developmental growth curves may reveal genetic controls that single time point analyses cannot because, in theory, there are an infinite number of growth curves that can result in the same final measurement.

Relatively few studies incorporate the entirety of organismal development. In part, this is because studying developmental variation adds not only significant time and cost to experiments, but also complexity to data analysis.

**Objectives**

The overarching objective is to understand the genetic underpinnings of plant morphology and the effects on plant yield. Specific goals were to: 1) characterize the mathematical functions that describe the expansion of organs such as leaves and stems, 2) ascertain how micrometeorological variation (for instance, temperature, light intensity, etc.) affects trait expression, and 3) evaluate correlations between aspects of leaf growth and other agronomically important traits such as flowering time.

Figure 1. Plots of leaf length as a function of time for one genotype of *Brassica rapa*. Circles are measured leaf lengths, and lines represent growth curves fit by Bayesian modeling to estimate the rate of growth, duration of growth, size when growth is 95% complete, and maximum size. Genotypes of this species differ in all of these growth parameters as estimated from our models.

Figure 2. Allometry plots of leaf width as a function of leaf length. Circles are measured leaf lengths and widths, and lines represent curves fit by Bayesian modeling to estimate aspects of leaf shape. Interestingly, shape was genetically independent of size, as shown in Figure 1.
Materials and Methods
We studied morphological traits in diverse cultivars of *Brassica rapa* (field mustard), which has been domesticated as turnip, diverse leaf crops such as pak-choi, the flower crop brocolatto, and the original canola oilseed crop. Plants were measured daily for the expression of morphological traits such as leaf length, leaf width, and stem height and phenological traits like flowering time, all of which may affect plant yield, depending on conditions in the growing season. We also recorded high-frequency micrometeorological data at the site, including daily temperature ranges, light intensity, and precipitation; abiotic factors like these can also have a pronounced effect on yield.

Results and Discussion
We identified mathematical functions of leaf growth (Figure 1) and leaf allometry (or shape) (Figure 2) and estimated coefficients for parameters of these functions for 130 unique genetic lines. We have mapped coefficients for leaf growth curves and allometry to unique genomic regions. Notably, the genomic regions that affect expansion patterns are not always the same as those that affect final size, indicating that our approach identifies novel genetic controls on leaf development. Further, the genetic controls on leaf size are often independent of leaf shape, indicating that agronomists could select for improvements in leaf shape that reduce water use or improve light interception without affecting overall plant size.

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