Experimental test of the combined effects of water availability and flowering time on pollinator visitation and seed set

M. Kate Gallagher, Diane R. Campbell

## Contact for owner of data:

Diane R. Campbell, drcampbe@uci.edu

## Year of study:

2016

## Location of study:

Field sites are located in two sub-alpine meadows located along County Highway 317/ Gothic Road (38°59'48.5"N 107°00'57.5"W, 2,992 m. and 39°00'20.3"N 107°01'53.5"W, 3,143 m.) located 5.5 and 7.2 km from the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Gunnison County, Colorado, USA (38°57’29” N, 106°59’06” W, 2,900 m.).

## Keywords:

*Bombus*, *Mertensia*, mutualism, phenology manipulation, pollinator visitation, species interactions, water manipulation

## Abstract:

Climate change will likely alter both flowering phenology and water availability for plants. The relative impacts of those two factors on plant reproductive success and whether those impacts are additive are unknown. We manipulated flowering phenology and soil moisture in a factorial experiment with a subalpine plant. We examined responses of floral traits, floral abundance, pollinator visitation, seed production and seed mass.  Reduced water led to shorter, narrower flowers that produced less nectar. Late flowering plants produced fewer and shorter flowers. Despite changes in floral morphology, changing water availability had less impact on pollinator visitation than did altering flowering phenology, which led to a decline in visitation over the season. The reverse was true for seed production and mass, which were enhanced by greater water availability. We detected interactions of phenology and water on pollinator visitor composition, in which late in the season plants subject to drought experienced a resurgence in visits by solitary bees and flies while well-watered plants were visited only by bumblebees. Despite that interaction, net reproductive success measured as seed production responded additively to the two manipulations. The results highlight the importance of assessing how co-occurring ecological responses to changes in climate may affect plant reproduction.

## Materials & Methods:

To test the extent to which effects of phenology on pollination and reproductive success vary with co-occurring changes in water availability, we manipulated both flowering onset and water availability in a factorial experiment using potted *M. ciliata* plants. Between 2012 and 2015, 120 plants were collected from a large *M. ciliata* population in Rustler Gulch. A portion of the plants were used for other studies in 2013 and 2015, but otherwise remained in trenches and overwintered in the ground under snow at RMBL until their use for this experiment. In 2016, potted plants were randomly assigned to one of three water treatments, dry, average, and wet. To inhibit flowering, potted plants were moved to Schofield Pass (39°00'54.98'' N, 107° 2'49.40'' W; 3,263 m.a.s.l.) in early June, where they were placed in a shaded snowbank under a mesh shade-shelter. Each week, 30 randomly selected plants, 10 per water treatment, were moved back to RMBL, where the higher light and warmer temperatures at low elevation induced them to flower at the experimentally chosen time.

Each week, thirty plants in their first week of flowering (10 per water treatment) were moved from RMBL to a meadow near the original source population in Rustler Gulch. Plants were arranged 30 cm apart into five randomized arrays of six plants, with 2 m between arrays. Each array included two plants of each water treatment. In week four, 12 plants stopped flowering mid-week and therefore we re-randomized the plants that had flowers remaining into three new arrays with six plants each. Where appropriate, we calculated the mean values per array of week four plants before and after the plants were rearranged, and then averaged those two values for each plant. To create distinct experimental populations*,* arrays were located 50 meters away from unmanipulated *M. ciliata* populations. A total of 114 plants flowered and were included in the experiment, for a total of four phenology treatment groups spanning four weeks (June 20 — July 17).

The water manipulations were maintained through the growing season (June 10 – August 1) and discontinued once seeds were collected. We watered pots manually with watering cans slowly and evenly to avoid pooling, in the mid to late afternoon to coincide with the timing of July thundershowers. Throughout the experiment, we measured soil moisture as volumetric water content (VWC) every third day using a 12 cm Campbell Scientific “HydroSense” probe inserted into the center of each pot (always before applying water). We used these VWC measurements to maintain soil moistures within the pots at levels that correspond with VWC levels in a previous water manipulation experiment where *M. ciliata* plants within naturally occurringpopulations received either 50% reduction in precipitation (dry pots), twice the historic average rainfall during July from 1990 to 2009 (wet pots), or average conditions (control; Campbell and Wendlandt 2013, Gallagher and Campbell 2017). In the end, we maintained the desired soil moisture levels by watering wet pots daily, control pots every other day, and dry pots every third day. Average VWC values for plots were analyzed with a linear mixed model with the main and interactive effects of water treatment and phenology week as fixed effects, and array nested in phenology week as a random effect. The water treatments led to 10.4 ± 0.4%, 12.7 ± 0.4%, and 17.5 ± 0.6% average VWC in the soil for dry, control, and wet pots respectively (Mean ± SEM), creating a gradient in soil moisture that did not vary significantly among phenology weeks (Water: χ22= 106.3, *P* < 0.0001, Phenology: χ23= 5.2, *P* = 0.2, Water 🞩Phenology: χ26= 1.44, *P* = 0.96, Figure 1A).

Note that we manipulated both factors within a realistic range of natural variation. The four phenology weeks corresponded closely with the range of flowering time onset in nearby natural populations (Gallagher and Campbell 2020). The water treatments of adding or subtracting 50% of average rainfall fell within the range of summer precipitation over the past few decades (Campbell and Wendlandt 2013).

## Measurements of floral traits, pollinator visitation, and reproduction

For each phenology week, we measured floral traits, including total abundance of flowers open during the phenology week, corolla size, and nectar volume and sugar concentration. We measured corolla width at the opening of the tube and corolla length from the base of the calyx to a randomly chosen corolla lobe for an average of 4.4 ± 0.4 flowers per plant. At the end of each week, after pollination observations were complete, individual flowers in each phenology group were labeled and bagged with fine mesh jewelry bags (Uline, Pleasant Prairie, WI, USA) to prevent further pollination and loss of seeds, and to provide a count of the total number of flowers open during that phenology week. For plants with flowers remaining at the end of each week, we measured nectar volume and percent sugar concentration 48 hours after plants were bagged (N = 71 plants). For an average of 2.6 ± 0.2 flowers per plant, we measured nectar volume using 5μl microcapillary tubes (Kearns and Inouye 1993) and percent sugar concentration using a handheld nectar refractometer (Bellingham + Stanley Ltd., Basingstoke, Hants, UK). No flowers remained for nectar measurements in week four, therefore we only include nectar data from phenology weeks 1-3 in our analyses. For each floral trait, we calculated the mean trait value of each potted plant, to be used as the response variable in our analyses.

Plants in each phenology group were open to pollination for one week. During that time, we conducted pollinator observations and tracked pollinator identity and the number of flowers visited during multiple 30-minute observation periods between the hours of 9:00 and 16:00. At the beginning of each observation period, we counted the number of open flowers per potted plant. We calculated mean pollinator visitation rate per plant as (total number of flowers visited) / (number of flowers available per hour of observations) averaged across the phenology week. Visitors were counted as pollinators if they crawled inside the flower corolla. We completed 25 hours of pollinator observations per phenology group. For each 150-minute round of observations to the five arrays we randomized the order of observations among arrays.

During 100 hours of pollinator observations to six plants at a time, we observed 340 floral visitors to experimental plants. The most common pollinators, bumblebees (*Bombus* *spp.)* and solitary bees (*Osmia spp.)*, accounted for 92.6% of floral visitors, with flies (Muscoidea and Syrphidae 7.1%) and a moth (0.3%) making up the rest. We excluded the moth from our analyses. For a metric of pollinator type, for each potted plant we calculated mean percent of visitors that were bumblebees as (100% × number of visitors that were bumblebees) / (total number of flower visitors per hour of observation) averaged across the phenology week.

All plants remained in the field until seeds were collected to standardize conditions after pollination exposure. We counted the total number of seeds produced per marked flower (as described by Forrest and Thomson 2010). We calculated the average seeds per flower for each potted plant as (number of mature seeds / number of flowers). Mature seeds from tagged flowers were collected in coin envelopes and transported to the University of California, Irvine to be weighed. We calculated mean seed mass for each plant as (mass of collected seeds / number of collected seeds). Seed mass included the mass of the elaiosome.

## References Cited:

Campbell, D.R., and Wendlandt, C. (2013). Altered precipitation affects plant hybrids differently than their parental species. American Journal of Botany, 100, 1322-1331.

Forrest, J. R., and Thomson, J. D. (2011). An examination of synchrony between insect emergence and flowering in Rocky Mountain meadows. Ecological Monographs, 81, 469-491.

Gallagher, M.K., and Campbell, D.R. (2017). Shifts in water availability mediate plant-pollinator interactions. New Phytologist, 215, 792-802.

## Who collected the data?

M. Kate Gallagher, Hannah Clements, Allie Hacker and Alex Faidiga

# Workbook: gallagher&campbell\_frontiersinecology&evolution\_data.xlsx

## Pollinator Visitation

Worksheet: exp3\_2016\_PolObs

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### date - Date

##### Date the data were recorded.

##### Date format: dd-mmm-yy

##### Type: Date

#### start – Start Time

##### Start time.

##### Start of observation period.

##### Time format: hh:mm (24hr clock, GMT-06:00)

##### Type: Time

#### end – End Time

##### End time.

##### End of observation period.

##### Time format: hh:mm (24hr clock, GMT-06:00)

##### Type: Time

#### period – Period

##### Time period of observation.

##### Time format: 30 (mm, 30 minute period)

##### Type: Time

#### weather – Weather

##### Weather at time of observation period.

##### Type: Text

#### colInit – Collector Initials

##### Data Collector Initials.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### AH = Allie Hacker

##### AF = Alex Faidiga

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric

#### totFlrsAv – Total Number of Flowers Available

##### Total number of open flowers available per plant.

##### Measured at the beginning of each observation period.

##### Type: Numeric

##### Measurement unit: Flowers

#### totflrsVis – Number of Flowers Visited

##### Number of flowers visited by the visitor.

##### Type: Numeric

##### Measurement unit: Flowers

#### totflrsNR – Number of Flowers Nectar Robbed

##### Number of flowers nectar robbed by the visitor.

##### Type: Numeric

##### Measurement unit: Flowers

#### noVisitors – Number of Visitors

##### Number of different visitors during that observation period.

##### Type: Numeric

#### noRobbers – Number of Robbers

##### Number of different nectar robbers during that observation period.

##### Type: Numeric

#### BombusVisits – Number of Bombus Visits

##### Number of visits by *Bombus* spp. during observation period.

##### Type: Numeric

#### nonBombusVisits – Number of non-Bombus Visits

##### Number of visits by non-*Bombus* spp. during observation period.

##### Type: Numeric

#### visID – Visitor Identification

##### The genus and species of the pollinator (if known), otherwise a description.

##### Number = number of visitor (i.e., visID2 if second visitor)

##### Type: Text

#### notes – Notes

##### Notes

##### Notes include details about visitor identification, behaviors, etc.

#### deInit – Data Entry Initials

##### Data Entry Initials

##### HC = Hannah Clements

##### Type: Text

## Floral Morphology

Worksheet: exp3\_2016\_floralMorph

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### flrCnt – Number of Flowers produced by plant

##### Number of Flowers produced by plant

##### Type: Numeric

#### corW – Corolla Width

##### Corolla width (for six flowers if available and an average).

##### Measured by sliding the calipers in the corolla and measuring the widest part of the corolla by slowly widening the calipers until the flower was taught.

##### Type: Numeric

##### Measurement unit: Millimeters

#### corL – Corolla Length

##### Corolla Length (for six flowers if available and an average).

##### Measured from base of corolla (where stem meets plant) to the edge of the tallest fringe.

##### Type: Numeric

##### Measurement unit: Millimeters

#### colInit – Colletor Initials

##### Initials of the person taking the measurements.

##### KG = Kate Gallagher

##### Type: Text

#### recInit – Recorder Initials

##### Initials of the person recording the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### colDate - Date

##### Date the data were recorded

##### Date format: dd-mmm-yy

##### Type: Date

#### note - Note

##### Notes

##### I noted instances of herbivory, nectar robbing, and the status of the plant.

##### Type: Text

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

## Stomatal Conductance

Worksheet: exp3\_2016\_stomCond

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### stomCond(3 Ws.) mmol/m2s (C0) – Stomatal Conductance

##### Stomatal conductance for three leaves.

##### First number is the conductance(?), second number in parentheses is the temperature

##### Type: Numeric

##### Measurement unit: mill-mols/meters squared per second (degrees Celsius)

#### colDate – Collection Date

##### Date the data were collected.

##### Date format: dd-mmm-yy

##### Type: Date

#### note - Note

##### Notes

##### Type: Text

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

## Soil Moisture Data

Worksheet: exp3\_2016\_soilMois

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### sm (%) – Soil Moisture (%)

##### Soil Moisture content (percent).

##### Type: Numeric

##### Measurement unit: Percent

#### period (m/s) – Period (m/s)

##### Period (meters per second).

##### Type: Numeric

##### Measurement unit: Meters per second

#### colInit – Colletor Initials

##### Initials of the person taking the measurements.

##### KG = Kate Gallagher

##### Type: Text

#### recInit – Recorder Initials

##### Initials of the person recording the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### colDate - Date

##### Date the data were recorded

##### Date format: dd-mmm-yy

##### Type: Date

#### note - Note

##### Notes

##### Type: Text

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

## Nectar

Worksheet: exp3\_2016\_nectar

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### necVol – Nectar Volume (μl)

##### 48 Hour Nectar Volume (μl)

##### We measured 48-h nectar volume using 5μl microcapillary tubes (Kearns & Inouye 1993, Morrant *et al.* 2009). We measured for three flowers (if available) and included an average.

##### Type: Numeric

##### Measurement units: Microliters

#### necConc – Nectar Sugar Concentration

##### Nectar Sugar Concentration

##### We measured percent sugar concentration (48-hr) using a handheld nectar refractometer (Bellingham + Stanley Ltd., Basingstoke, Hants, UK). We measured for three flowers (if available) and included an average.

##### Type: Numeric

##### Measurement units: Percent

#### colDate - Date

##### Date the data were recorded

##### Date format: dd-mmm-yy

##### Type: Date

#### colInit – Colletor Initials

##### Initials of the person taking the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### recInit – Recorder Initials

##### Initials of the person recording the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

#### note - Note

##### Notes

##### Type: Text

## Vegetative Traits and Herbivory

Worksheet: exp3\_2016\_vegandherbiv

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### height - Height

##### Height.

##### Ramet height as measured from the base to the tip of the leaves. Ramet heights measured for three flowering stalks (if available) and include an average.

##### Type: Numeric

##### Measurement unit: centimeters

#### lfCnt – Leaf Count

##### Leaf count.

##### Total leaf count on each ramet for three total (if available) (including dead leaves).

##### Type: Numeric

##### Measurement unit: Leaves

#### herbivory – Herbivory

##### Number of leaves with visible herbivory damage.

##### Number of leaves with herbivory damage over the total number of leaves on each ramet.

##### Type: Numeric

##### Measurement unit: Leaves

#### note - Note

##### Notes

##### I noted instances of herbivory.

##### Type: Text

#### colInit – Colletor Initials

##### Initials of the person taking the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### recInit – Recorder Initials

##### Initials of the person recording the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### colDate - Date

##### Date the data were recorded

##### Date format: dd-mmm-yy

##### Type: Date

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

#### note - Note

##### Notes

##### We noted if other damage to plant, for instance presence of caterpillar.

##### Type: Text

## Nectar Robbed Flower Identification

Worksheet: exp3\_2016\_NRFlrIDs

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### NRFlrID – Nectar Robbed Flower Identification Number

##### Nectar Robbed Flower Identification Number, unique within each Plant Identification Number.

##### Type: Numeric (Factor)

#### colInit – Collector Initials

##### Initials of the person taking the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### colDate - Date

##### Date the data were recorded

##### Date format: dd-mmm-yy

##### Type: Date

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

## Seed Set

Worksheet: exp3\_2016\_seedCnt

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### flrID – Flower Identification Number

##### Flower Identification Number.

##### The number assigned to each individual flower that was open that week on each plant. Numbers are unique on a per plant basis.

##### Type: Numeric (Factor)

#### seedCnt –Seed Count

##### Total Seed Count.

##### Number of seeds counted per flower per plant.

##### Type: Numeric

##### Measurement unit: Seeds

#### recInit – Data Recorder Initials

##### Initials of the person counting and recording the seeds.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### Type: Text

#### colDate - Date

##### Date the data were recorded

##### Date format: dd-mmm-yy

##### Type: Date

#### note - Note

##### Notes

##### Type: Text

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

## Phenology Transects – Phenology of wild M. ciliata plants

Worksheet: exp3\_2016\_mcPhenTransects

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### transect – Transect

##### Transect.

##### We sampled within five transects that contained ten marked plants each.

##### Type: Numeric (Factor)

#### mcID – Mertensia ciliata Identification Number

##### Plant Identification Number within transect.

##### This is a number I assign to each plant within each transect. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### budCnt – Bud Count

##### Bud Count.

##### The number of buds present each week at time of data collection.

##### Type: Numeric

#### budNR – Buds Nectar Robbed

##### The number of buds with evidence of nectar robbing.

##### Type: Numeric

#### flrCnt – Flower Count

##### Flower Count.

##### The number of open flowers present each week at time of data collection.

##### Type: Numeric

#### flrNR – Flowers Nectar Robbed

##### The number of flowers with evidence of nectar robbing.

##### Type: Numeric

#### seedCnt – Seed Count

##### Seed Count.

##### The number of seeds produced for flowers open during each week collection period.

##### Type: Numeric

#### note - Notes

##### Notes

##### We noted instances of herbivory, disease, death, or anything else unusual.

##### Type: Text

#### colInit – Collector Initials

##### Initials of the person taking the measurements.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### AH = Allie Hacker

##### Type: Text

#### colDate - Date

##### Date the data were recorded

##### Date format: dd-mmm-yy

##### Type: Date

#### recInit – Recorder Initials

##### Initials of the person recording the counts.

##### KG = Kate Gallagher

##### HC = Hannah Clements

##### AH = Allie Hacker

##### Type: Text

#### deInit – Data Entry Initials

##### Initials of the person entering the data.

##### HC = Hannah Clements

##### Type: Text

## Master Plant List

Worksheet: exp3\_2016\_masterplantlist

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### yearCol – Year Collected

##### The year the plant was collected (2013 or 2015).

##### Type: Numeric (Factor)

#### note - Notes

##### Notes.

##### Other important information to note.

##### Type: Text

## Means for Analysis

Worksheet: exp3\_meansForAnalysis

#### week - Week

##### The week the data were collected (i.e., 1).

##### Type: Numeric

##### Measurement unit: Weeks

#### array – Array

##### Array.

##### We used five randomized arrays containing six plants each; there were two plants of each treatment per array.

##### Type: Numeric (Factor)

#### treat - Treatment

##### Treatment.

##### There were three treatments, designated D (drought), C (control) and A (water addition).

##### Type: Text

#### plantID – Plant Identification Number

##### Plant Identification Number.

##### This is a number I assign to each plant. The first two digits correspond to the year the plant was tagged, the second to the experiment number, and the last three are unique to the plant.

##### Type: Numeric (Factor)

#### yrCol – Year the plant was collected from the wild

##### Year the plant was collected from the wild.

##### Type: Numeric (Factor)

#### noteGeneral – General Notes

##### General notes about the plant and how it was used in the experiment.

##### Type: Text

#### mVWC – Mean Volumetric Water Content

##### Mean soil moisture content (percent).

##### Type: Numeric

##### Measurement unit: Percent

#### mHeight – Mean plant height

##### Mean plant height.

##### Ramet height as measured from the base to the tip of the leaves. Ramet heights measured for three flowering stalks (if available) and include an average.

##### Type: Numeric

##### Measurement unit: centimeters

#### mHerb – Mean herbivory

##### Mean leaf herbivory for entire plant.

##### Number of leaves with herbivory damage over the total number of leaves on each ramet.

##### Type: Numeric

##### Measurement unit: Leaves

#### noteVeg – Notes on vegetative traits

##### Notes

##### I noted instances of herbivory and the status of the plant.

##### Type: Text

#### flrCnt – Number of Flowers produced by plant

##### Number of Flowers produced by plant

##### Type: Numeric

#### mcorW – Mean corolla width

##### Mean corolla width (for six flowers if available and an average).

##### Measured by sliding the calipers in the corolla and measuring the widest part of the corolla by slowly widening the calipers until the flower was taught.

##### Type: Numeric

##### Measurement unit: Millimeters

#### mcorL – Mean corolla length

##### Mean corolla length (for six flowers if available and an average).

##### Measured from base of corolla (where stem meets plant) to the edge of the tallest fringe.

##### Type: Numeric

##### Measurement unit: Millimeters

#### noteCor – Notes about corolla measurements

##### Notes

##### I noted instances of herbivory, nectar robbing, and the status of the plant.

##### Type: Text

#### mNecVol – Mean Nectar Volume (μl)

##### Mean 48 Hour Nectar Volume (μl)

##### We measured 48-h nectar volume using 5μl microcapillary tubes (Kearns & Inouye 1993, Morrant *et al.* 2009). We measured for three flowers (if available) and included an average.

##### Type: Numeric

##### Measurement units: Microliters

#### mNecConc – Mean Nectar Sugar Concentration

##### Mean Nectar Sugar Concentration

##### We measured percent sugar concentration (48-hr) using a handheld nectar refractometer (Bellingham + Stanley Ltd., Basingstoke, Hants, UK). We measured for three flowers (if available) and included an average.

##### Type: Numeric

##### Measurement units: Percent

#### mVisRate - Mean pollinator visitation rate per plant

##### Mean pollinator visitation rate per plant as (total number of flowers visited) / (number of flowers available per hour of observations) averaged across the phenology week.

#### sBombusVisits – Sum of Bombus Visits

##### Total number of visits by *Bombus* spp. to the plant (summed over the entire experiment)

##### Type: Numeric

#### sNonBombVis – Sum of Non-Bombus Visits

##### Total number of visits by Non-*Bombus* spp. to the plant (summed over the entire experiment)

##### Type: Numeric

#### sVis – Sum of visits

##### Total number of visits by any species to the plant (summed over the entire experiment)

##### Type: Numeric

#### sbbVis – Sum of Solitary bee visits

##### Total number of solitary bee visits to the plant (summed over the entire experiment)

##### Type: Numeric

#### sflyVisits – Sum of fly visits

##### Total number of fly visits to the plant (summed over the entire experiment)

##### Type: Numeric

#### seedCnt –Seed Count

##### Total Seed Count.

##### Number of seeds counted per flower per plant.

##### Type: Numeric

##### Measurement unit: Seeds

#### mSeed – Mean Seed Count

##### Mean Seed Count.

##### Mean of seeds counted per flower per plant. We calculated the average seeds per flower for each potted plant as (number of mature seeds / number of flowers produced). Mature seeds from tagged flowers were collected in coin envelopes and transported to the University of California, Irvine to be weighed.

##### Type: Numeric

##### Measurement unit: Seeds

#### sMass – Seed Mass

##### Mass of the total number of seeds counted per flower per plant.

##### Type: Numeric

##### Measurement unit: mg

#### msMass – Mean Seed Mass (mg)

##### Mean mass of seeds counted per flower per plant.

##### We calculated mean seed mass for each plant as (mass of collected seeds / number of collected seeds). Seed mass included the mass of the elaiosome.

##### Type: Numeric

##### Measurement unit: mg