Purpose: To investigate whether climate change alters the reproductive success of plants by changing how bees forage.

Background and Significance:

Climate change is having a huge impact on ecological systems, especially by changing interactions between organisms. For example, earlier spring temperatures have changed environmental cues, and many organisms are advancing the timing of major events in their life such as blooming or mating (Parmesan and Yohe, 2003). However, variation amongst interacting organisms in their responses to climate change can lead to temporal or spatial mismatch of their phenologies which has repercussions for both parties (Cleland et al 2007).

Plant-pollinator interactions are an example of this. Mutual dependency is common to many plants and pollinators. In western Washington prairies, bee foraging behavior is critical for plant reproduction, so a shift in the timing of prairie species’ blooms could alter which species receives more visits from bees, and thus how much seed each blooming species produces. Bees are the most important insect pollinators in this system. Plants that bloom at the same time can compete for bee visitation (Waser 1978).

Studies have shown that individual bees of same species can specialize in different flower species(flower constancy) (Bolnick et al 2003). If bees specialize on the flower species they first encounter, the blooming time of prairie flowers could affect their reproductive success. **We hypothesize that when bees forage on two flower species, the flower species that bloom first will receive more bee visitation and have higher seed production.**

Materials and Methods:

We acquired three Bombus impatiens beehives from Koppert Biological System(Michigan, USA). Colonies were **placed in a machine that** the daytime was set from 9am to 9pm. Thedaytime temperature was set at 24C and nighttime temperature was set at 23.4 C. Pollen and additional nectar were provided directly to the hive as needed.

Two plant species, *Hypochaeris radicata* and *Campanula rotundifolia*, were used in the experiment. *Hypochaeris radicata* were grew in University of Washington Botany Greenhouse and *Campanula rotundifolia* were acquired from **(the greenhouse in prairie).** During experiment period, plants were placed in the greenhouse and covered with () to minimize pollinator contact. Plants were water daily.

Experimental Design

(i)Experimental Flower Arrays

Experimental Flower Arrays consisted of 40 blooming flowers of *Hypochaeris radicata* and/or *Campanula rotundifolia.* Different numbers of individual plants were used in different flower arrays. In every flower array, 5 HypRad and/or 5 CamRot flowers were randomly chosen and marked with white colored tape. Flower Arrays were placed in the foraging arena during bee foraging period. The marked flowers were bagged after bees finished foraging bout.

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|  | Day1(A) | Day2(B) | Day3( C) | Day4 (D) | Day5(E) |
| Treatment1 | 100% HypRad | 75%Hyp+25%Cam | 50%Hyp+50%Cam | 25%Hyp+75%Cam | 100%CamRot |
| Treatment2 | HypRad+CamRot | HypRad+CamRot | HypRad+CamRot | HypRad+CamRot | HypRad+CamRot |
| Treatment3 | 100%CamRot | 75%Cam+25%Hyp | 50%Hyp+50%Cam | 25%Cam+75%Hyp | 100%HypRad |

\* 100%= 40 blooming flowers

(ii) Bee foraging experiment

Colonies were connected to the transparent plastic cups with ~2cm paper tissue ball with saturated sugar water to attract bees. The first 4 bees came out from the hives were used for overnight training period. Bees were individually marked with whiteout on the dorsal thorax with two different colors of lanes represent hive and treatment, respectively.

Only one treatment was performed at a time; three treatments were performed consecutively and began at the beginning of September. Experiment was perform in the foraging arena, a 91cmX 85cmX 85cm Rectangular cuboid that made of PVC pipes and sliver Aluminum window screens, in the greenhouse.

The day before the five-day period treatment started, 12 marked bees were allowed to stay in the foraging arena with flower arrays for overnight training period (11pm-930am). The first 2 bees of each hive that were able to complete one foraging bout on the first day were continued used for the experiment. During the treatment period, the individual bees were isolated in the clear plastic cups individually. We used 6 bees from 3 colonies in each treatment; 18 bees for the whole experiment.

Bee foraging experiment was performed between 10am-5pm daily. Bees were fed with sugar water a minute before releasing into foraging arena. Only one bee was released into the foraging arena at a time to prevent interact between bees. We defined a complete forage bout as forage on more than 10%( 4 flowers) of flower arrays within 30 second of interval; Incomplete forage bout as forage on less than 10% of flower arrays in 30 minute forage time; Unwilling to forage as fail to forage on any flower on two 30 minute forage time. After finishing forage bout, bees were captured back to plastic cup and provided with ~ 2cm saturated sugar water paper tissue ball.