

Plant Interactions

INTRODUCTION

Competition in plants may be thought of as “those hardships which are caused by the proximity of neighbors” (Harper 1961). Hardships may be due to the decreased availability of light, water, or nutrients to any individual plant when its canopy or root area overlaps with that of another individual. Therefore, the degree of crowding in an area will have an important effect on the amount of overlap between individuals and the mean growth of individuals in an area. Competition may be within a species (*intraspecific*) or between individuals of different species (*interspecific*). Differences in growth form (shape of leaves and arrangement on stem), root depth, development rate, daily pattern of water and nutrient uptake from the soil, and photosynthetic pathway may all influence the magnitude of competition.

In this exercise, you will be measuring the effect of competitor density on the growth of plants. You will be able to design your own experiment to test hypotheses about expected differences in competitive effects between species under different environmental conditions. You will also get to tour the CMU greenhouse and observe plant features that allow them to survive dry, humid and altogether *wet* environments.

OBJECTIVES

During this laboratory exercise you will

- Generate hypotheses regarding the outcome of competition between two plant species.
- Design and conduct an experiment to test competition between two potential plant competitors.
- Learn how to perform a regression analysis and how to compare the slopes of two regression equations.
- Discover some of the many adaptations that allow plants to survive conditions of differing temperature and moisture.

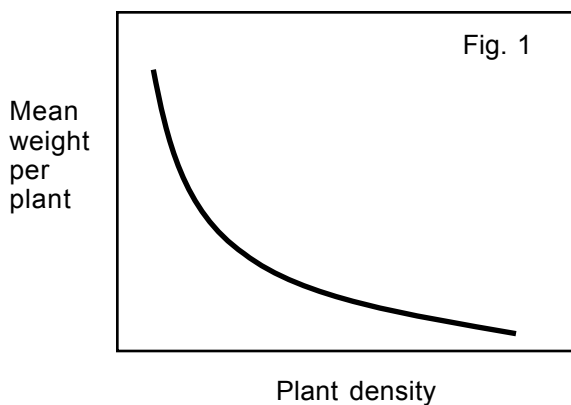
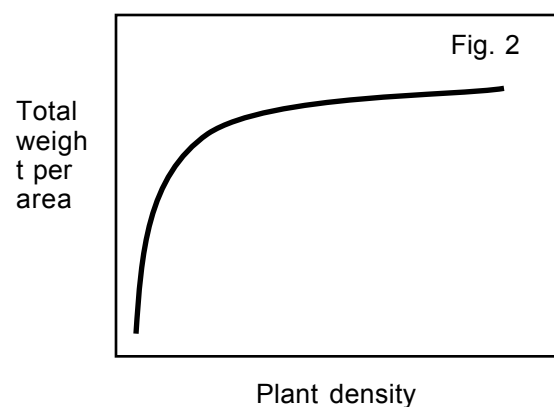
KEY WORDS

You should be familiar with the following terms:

intraspecific competition	Law of final yield	carrying capacity
interspecific competition	reciprocal yield equation	monoculture
treatment	coefficient of competition	indicator
replicate	nitrogen fixer	competitor
additive design	C ₄ pathway	

BACKGROUND

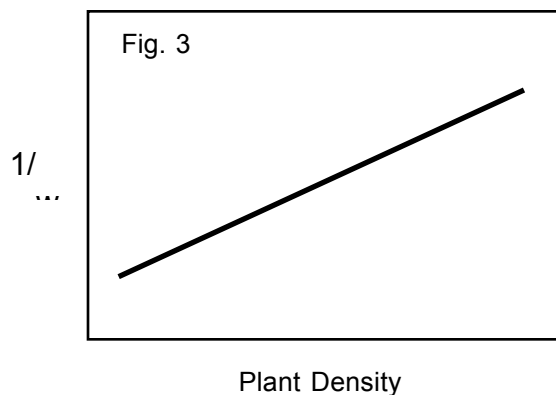
The effect of intraspecific competition in plant populations is usually examined by planting the species over a range of densities. The most common result is that the mean weight per plant decreases as density increases (Fig. 1) so that total yield (weight per area) approaches some constant value (Fig. 2). This result of diminishing returns is called the **Law of Final Yield** (Harper 1977). We can think of this constant yield as the carrying capacity (in terms of biomass) of the environment. **Carrying capacity** is the number, or mass, of individuals that can exist in a particular environment at any one time. Graphs such as figures 1 and 2, can be used to approximate the optimal planting density for a particular crop – the density beyond which total yield no longer increases.



You may have noticed that the mean weight per plant decreases in a non-linear fashion as plant density increases. This non-linear relationship is difficult to analyze statistically. If, however, we transform the non-linear relationship into a linear relationship, we can analyze the results using a simple linear regression. A **transformation** is simply a mathematical manipulation of one or both measured variables. The best transformation in this situation involves calculating the reciprocal of mean plant weight ($1/w$). The reciprocal of mean plant weight is related to plant density in a linear fashion (Fig. 3) according to the following formula:

$$1/w = a + b \cdot D$$

Where w = mean plant weight, D = density, a = reciprocal of the maximum mean plant weight, and b = coefficient of competition. This formula is called the **reciprocal yield equation**. A large (positive) value of b (steep slope) implies a strong competitive effect.



Most plants, however, do not live in a **monoculture** but experience interspecific competition from a number of other species. Even crops must share their environment with various weed species. To examine the effects of interspecific competition, you can use an experimental design similar to the one described above for intraspecific competition. In this case, you have two species, an **indicator** species (i) and a **competitor** species (j). If you keep the density of species i constant and vary the density of species j, you will be able to measure the effect of species j on species i. This type of experiment is referred to as an **additive design**.

because competitors are added to indicators so that the total density of the mixture increases (Harper 1977).

If the density of the indicator species is kept low enough so that intraspecific competition is weak or non-existent, we can use the reciprocal yield equation to describe interspecific competition only. In this situation, w = mean of the indicator species, D = density of the competitor species, a = reciprocal weight of the indicator when no competitors are present ($D=0$), and b = competitive effect of species j on species i .

Using the above design and analysis, students in each laboratory section will conduct experiments to test hypotheses about the interaction between two likely competitors. The plant species available in this exercise were chosen because they are potential competitors under natural conditions.

SUGGESTED EXPERIMENTS

Every laboratory section will conduct *two* experiments, each consisting of 5 density treatments. A single treatment consists of one indicator species and one competitor species grown in a single pot. Each treatment will be replicated *three* times. Therefore, there you will need 15 pots for each experiment. You can design experiments to test different combination of species or the same combination under different environmental conditions. Some suggested designs are given below.

1. Compare intensity of competition (b) for two competitor species on a single indicator species. Choose your species so that you can develop hypotheses about which species should be the strongest competitor from knowledge of its morphology or physiology. For example, you could compare several species of similar growth form but different seed size. If you include the same species as both indicator and competitor, you can compare the intensity of intraspecific to interspecific competition.
2. Compare the intensity of competition for two indicator species with the same competitor species. Again, choose species so that you can develop hypotheses about likely outcomes.
3. Compare the same species pair, reversing which one is the indicator and which the competitor. Is one species a stronger competitor than the other?

4. Compare the same species pair under various resource levels. Do different levels of fertilizer, water, or light alter the intensity of competition (b)? What might be the outcome of competition between a legume and grass under low and high nitrogen fertilization?
5. Compare the same species pair with the competitor introduced at different times (e.g., one week before indicator, simultaneous with indicator, one week after indicator). You can mimic different times of planting by choosing species with different germination times.

SPECIES SELECTION

Four grass species and two legume species will be available for experimentation (see below). Consider the specific adaptations of each species (growth form, seed size, nutrition, and photosynthetic pathway) as you design your experiments. The seeds of the various species vary in size. How might seed size affect competition? The legumes are **nitrogen fixers**. They have symbiotic bacteria (*Rhizobium*) in root nodules. These bacteria convert atmospheric nitrogen into a form utilizable by the plant. How might this effect the outcome of competition with a non-nitrogen fixing species or another legume? Millet is the least closely related grass species. It has a C₄ photosynthetic pathway whereas all the other species have a C₃ pathway. The **C₄ pathway** allows a plant to photosynthesize more efficiently in hot, high light intensity environments. Does millet have an advantage when light is high and soil moisture low?

Family Leguminosae

red clover (*Trifolium pratense*)

alfalfa (*Medicago sativa*)

Family Gramineae

Subfamily Festucoideae

annual bluegrass (*Poa annua*)

oats (*Avena fatua* var. *sativa*)

corn (*Zea mays*)

Subfamily Paniceae

millet (*Pennisetum spicatum*)

DIRECTIONS

PLANTING PROCEDURE

1. Prepare 15 four-inch pots for each experiment. Use tape to label each pot with indicator name, competitor name, competitor density, replicate number, and lab section. Remember that there should be 5 density treatments with 3 replicates each. Fill each pot with soil.
2. Calculate seeding rate. For best results, you should have 2 indicator plants per pot. Competitor plant densities should be 0, 2, 4, 8, and 16. Because all seed will not germinate, you should plant 3 indicator seeds in each pot. Plant 0, 3, 6, 11, and 20 competitor seeds in appropriate pots.
3. Plant seeds by distributing them evenly across the soil surface. Plant at a depth of 2.5-3 times the seed size. Place a plastic toothpick next to each indicator seed. This will help you find the plants after the competitor species germinate.
4. Put all pots for one experiment in a single plastic tray. Label tray with treatment ("no fertilizer", "inoculate"), if needed.
5. Check the pots every week for germination of indicators and later for their survival. If more seeds than expected germinate, thin plants to appropriate density.

HARVEST

All plants will be harvested and weighed after 7 weeks. Students should harvest only those pots they planted.

1. Carefully pull each plant out of the soil, removing the indicators first.
2. Count the number of surviving indicators and competitors.
3. Clip the roots from each plant and measure the total wet weight of all indicators and competitors. Calculate mean indicator wet weight.

Optional:

4. Put the indicators and competitors in a plant press between pieces of newspaper and dry in an oven at 65°C for 48 hours.
5. Measure the dry weight of all indicators and competitors and calculate the mean indicator dry weight.

ANALYSIS

1. Calculate the reciprocal mean plant weight ($1/w$) for the indicator species in each pot. Use wet weight.
2. Create two graphs for each experiment. On the first, plot $1/w$ against final competitor density. On the second, plot $1/w$ against final competitor weight. There should be 4 graphs per laboratory section.
3. Perform a regression analysis and calculate the reciprocal yield equation for each experiment.
4. Compare the slopes of the two reciprocal yield equations (b_1 vs b_2).

DISCUSSION QUESTIONS

1. What hypotheses were you testing in your experiments? What reasoning led you to develop these hypotheses?
2. Did your results support your hypothesis? What conclusions can you draw?
3. What abiotic or biotic factors in nature might change the competitive outcome you observed?

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