Experimental Evidence for Plant Competition

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Introduction

Competition refers to the process and the consequences of organisms seeking limited resources in the presence of each other. For plants we can further define competition as those hardships caused by the proximity of neighbors (Harper 1961). Plant populations often exhibit **intra-specific** as well **inter-specific competition**; neighbors of the same or a different species can affect plant density and size. We will examine competition between oats and lentils. Both species are grown as crops in the grassland environments of eastern Washington. Two techniques will be employed here: a **replacement series** that involves sowing two species in varying proportions while maintain a constant overall density and a **density series** in which densities among monocultures are varied.

Materials

Seeds (oats and lentils)	Tape
Potting mixture	Marking pens
Plastic trays	

Procedure

Each group will be responsible for setting up the experiment before it is transferred to the greenhouse. The lab instructor is responsible for transporting the trays to the greenhouse.

Replicates of each set of proportions (one per lab group) will be established according to the following design:

Oats:Lentils				
100:0	75:25	50:50	25:75	0:100

Fill the bottom 2/3 of each tray with potting mixture. Gently compress the potting mixture to form a firm (but not hard) seed bed. Count out the seeds to be used in each try. If 100 seeds are used per tray, then for tray 2 you will sow 75 oat seeds and 25 lentil seeds. Broadcast sow the seeds across the surface of each tray. Cover the seeds with a then layer of soil, but do not water the seeds.

There is an important problem not examined by this procedure: over time most plant populations change in density, even if not occurring a mixture. Consequently, you will also add a density series to the design. In these trays 25, 50 or 75% of the seeds of one species only will be sown to detect the magnitude of any intra-specific competition. The whole design will include a total of 11 trays (5 trays in the replacement series plus another 6 trays for the density series).

Both species are sown in this design

75:0 50:0 25:0

You will follow emergence and growth of these two species in monoculture and in mixtures. It is important to rotate the trays across the benches periodically to ensure that all trays experience the same overall environment (**note: this will be done for you, but failure to rotate trays results in well-known 'bench effects', i.e., differential growth among rays that is not a consequence of the different treatments or species proportions**). At the end of the experiment, dry weight will be determined by harvesting the plants at the ground level. Yield could also be expressed as the number of seeds or average seed weight, but our plants will probably not produce seeds by the end of the semester. Comparisons will be made to evaluate intra-specific and inter-specific competition, and which species is the better competitor.

Analysis of Results

Results of experiments using a replacement series can potentially take any of four basic forms (Harper 1977). In each of these diagrams, there are three plots for yield: one for each species and a third uppermost curve, which is the combined yield of the two species. Growth is measured as dry weight, seed number or seed weight.

Model I. In this model each species contributes to the total yield in the mixture in direct relation to its proportion among the sown seeds. (That is, the plots for both species are linear.) Two scenarios produce such graphical results. The density of the mixed population can be so low that individuals do not compete (the yield of each species is then linearly related to the number of its plants). This outcome can be detected by repeating this replacement design at several densities. In the second scenario, the density is sufficient for plants to compete with each other and each species has the same effect on the other. In both scenarios the yield of the mixture is predictable from the yield of the monocultures. Assuming the density is sufficient for individuals to compete with each other, experimental results resembling this model suggest the two species make the same demands on resources. Yields of the two monoculture need not be equal; the two species may be making similar demands on resources but converting them with different efficiencies or to different products.

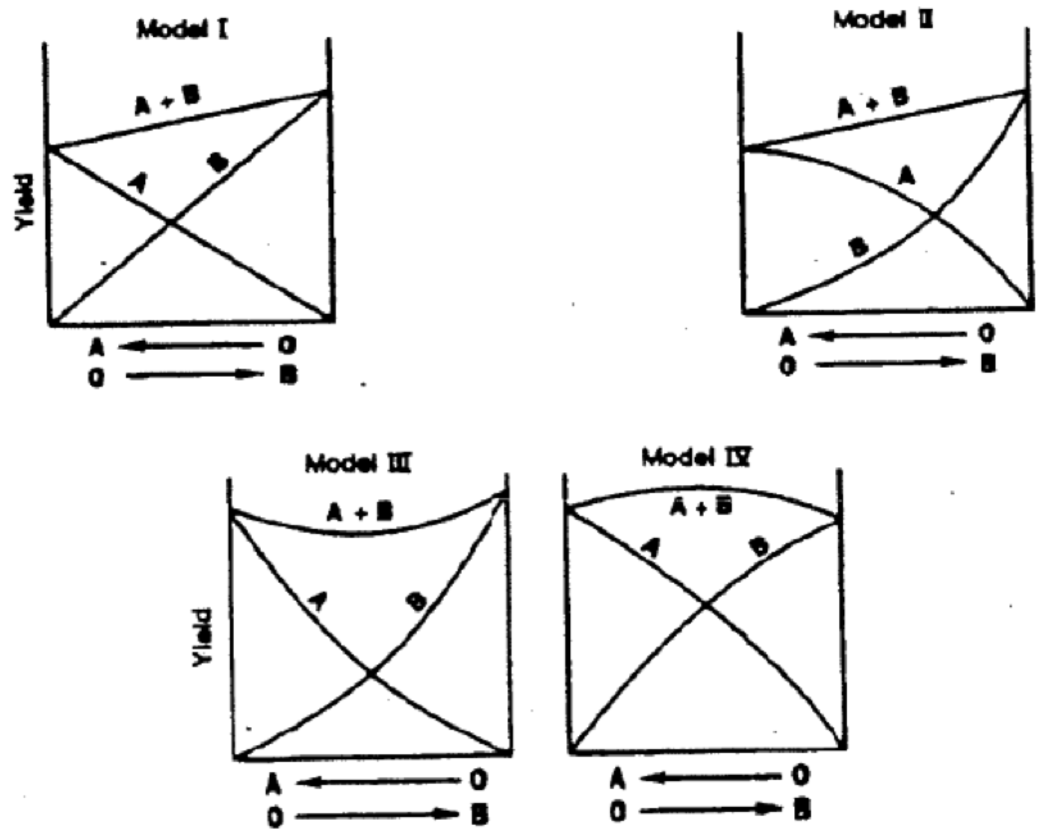

Figure 1: Models of competition

Model II. In this model the effect of one species on another is greater than the reverse case, a result indicated by the flexure in the curves. Species A is capturing proportionally more resources across the replacement series than would be predicted from a monoculture (its curve has a convex shape); Species B is capturing less (its curve has a concave flexure). For Species B the consequences of interspecific competition are grater than the consequences of intraspecific competition. The species yielding most in monoculture need not be the most successful species in the mixture; i.e., a species productive in monoculture may be an ineffective competitor.
Model III. This third result occurs when the effect of interspecific competition is greater on each species than is the effect of intraspecific competition. This model includes cases in which neither species contributes to the total yield the amount predicted from the density series. (Not in particular the total yield in the 50:50 mixture.) This outcome could result if Species A consumed more of a limiting nutrient than it could use (so-called luxury consumption), but in doing so it hindered the growth of Species B. In turn Species B by virtue of greater height shaded Species A and prevented Species A from utilizing these nutrients to the fullest.
Model IV. In this last model the effects of potential interspecific competition are less than the effects of intraspecific competition. The curves for both species are convex, and of course the total yield curve is also convex. This model includes cases of symbiosis in which each species benefits from the presence of the other. A more usual situation with this result occurs when each species avoids some competition with each other. For example, the model include cases in which the growth of Specie A was limited by one resources, such as nitrogen, while Species B was limited by phosphorus. Active growth of the species in different species, such as one growing actively in early spring, while the other is active in summer can also produce such sets of curves.

Questions to think about:

1. Is there any evidence of intra-specific competition in the density series?
2. In the replacement series, which model most closely resembles your results?
3. Does the species with the largest biomass in monoculture appear to be the least affected by the other species? Would the largest species always be the superior competitor?
4. Do you see any limitations in using mixtures of only 50:50 and 75:25 for these experiments?
5. How could grazing or pathogens in one species but not the other affect these results?

Assignment:

Your assignment this week is to construct three graphs from your data, each with an appropriate caption. The first graph will show how biomass production per lentil seed changes with the density of lentils. You will have two lines, one for lentils raised by themselves and another with lentils raised with oats. The second graph will be similar, only focusing on oats. What will these graphs tell you about competition?
The last graph will be replicating the replacement series graphs seen above. What does this graph tell you about competition?

Literature Cited

Harper, J.L. (1961). Approaches to the study of plant competition. In: Mechanisms in Biological Competition (F.L. Milthorpe, ed.). Symp. Soc. Exp. Biol. 15:1 – 39.

Harper, J.L. (1977). The Population Biological of Plants. Academic Press, New York.

Plant Competition Experiment Data

Tray	Oats planted	Lentil planted	Dry wt oats	Dry wt lentils	biomass/seed
1	25	0		0	
2	50	0		0	
3	75	0		0	
4	100	0		0	
5	75	25			
6	50	50			
7	25	75			
8	0	100	0		
9	0	75	0		
10	0	50	0		
11	0	25	0		