Plant Breeding for Aphid Resistance: A simulation

How can breeders achieve resistance using genetic models?

The soybean aphid, *Aphis glycines*, is an invasive insect pest. If a farm has an aphid infestation, one option to control it is insecticides. Many insecticides have side effects, or are less than effective at control. Another potential strategy is host plant resistance to soybean aphids. Several Rag genes have been discovered that may help to improve resistance in soybeans. This is an important advancement as soybean aphids cost farmers between $2-$5 billion per year due to yield loss and cost of treatments.

In this simulation, you are a member of a plant breeding team. You goal is to find the most resistant plants to soybean aphids. You will use dice to determine the genotype (the gene combination), environmental value (the effect of the environment on the plant's ability to produce resistance) and phenotype combinations of five different plants containing Rag genes. You will choose the best breeding parents from those plants, to then create the most resistant plants to aphids.

For the purpose of this activity, the following definitions may help:

> ***genotype*** – the gene combination for a trait that is part of DNA (i.e. the section of DNA that will determine the resistance of a soybean)
>
> ***environmental*** value – based on the combination of factors that influence how genes are expressed (hours of sunlight, soil pH, amount of rainfall), so that the higher the value, the better the "fitness" to grow in the region.
>
> ***phenotype*** – the physical expression of a trait; what we can see (i.e. when planted, the most resistant soybeans will show the least damage from aphids or aphids will not attack them).
>
> ***allele*** – the form of a gene for a trait (may be two or more depending on the gene) (i.e. resistance is one form of the gene, while non-resistant is another form of the same gene)
>
> ***homozygous*** – a genotype that contains two of the same alleles for a trait.
>
> ***heterozygous*** – a genotype that contains two different alleles for a trait.

Materials
Plant breeding chart
Calculator or spreadsheet
A set of two six-sided dice per 4 person team

Procedure

1. Roll one die to determine the genotypic value of your first plant. Odd numbers (1,3,5) indicate an allele of the favorable trait and are assigned a value of 1 and even numbers indicate an allele of the absence of the trait and are assigned a value of 0. Roll the die nine more times and fill in the first and second row of the plant 1 chart with the combination of 1's and 0's determined by your dice rolls filling in from left to right in the top row, then the bottom row. The genotypic value is the sum of the 1's and 0's.
2. Roll both dice to determine the environmental value of the parent plants. (Remember: the higher the number, the more fit the plant is to live in the environmental conditions that are present in your region.)
3. Add the genotype value together with the environmental value to get the phenotype value. Fill in these values on the Plant Breeding Chart.
4. Repeat step 1-3 for each additional plant up to five. Determine the total genotypic value, the environmental value and the phenotypic value for each.

Maintaining Our Yield

5. Circle the table of each of the parents you want to use to cross for the favorable traits. Number their tables 1 and 2. Check to see if parent one is homozygous for trait 1 (i.e. has both 0's or 1's in the first column). If yes, put that 0 or 1 in the top row of the table in column 1 for each of the F1 generation plants. If no, leave that space blank. Check to see if the parent is homozygous for trait 2, 3, 4, and 5. Only add the info to the top row if parent one is homozygous for the trait. Check parent two the same way, adding the information if homozygous to the second row of each plant. (See below for an example.)

Plant 1 Parent

1	1	0	0	1
0	1	1	1	1

G + E = P

__7___+__9___=__16___

Plant 2 Parent

1	1	0	1	0
1	1	0	1	1

G + E = P

__7___+__12__=__19___

F1

Plant

1	1	0	1	1
1	1	0	1	1

G + E = P

__8___+__7__=__15___

6. If parents are not homozygous for a trait, leave the space blank. Determine the allele for the blanks by rolling the die again (odd numbers = 1; even numbers = 0).
7. Roll the dice to determine the environmental value of each offspring. Add the environmental value to the genotypic value to get the phenotypic value of each.
8. Analyze your F1 generation. Is there a plant that will provide all 5 Rag genes? What is your next step as a plant breeder?
9. Continue to cross plants until you have achieved the best offspring to resist soybean aphids.

Reflection

1. What is the hardest part of plant breeding? How does this activity compare to actual plant breeding?

2. Where were decisions required?

3. What are the technologies that would help improve plant breeding to achieve soybean aphid resistance?