Anticipating effects of various seed bank reproduction schemes using Mendel's Accountant (Population Genetics Simulator).

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Abstract:

Mendel's Accountant is a user-friendly, forward-time population genetics simulator developed to incorporate as much biological realism as possible, yet still run on ordinary laptops for many problems of interest. It has been designed for research and teaching of the mutation-drift-selection balance in diploids (see "Introducing Mendel's Accountant…"—abstract in section A1). Mendel's Accountant provides opportunity to investigate the effects of various factors on population fitness and allele loss over generations. Determining minimum population sizes required to preserve genetic diversity in seed banks is critical to maintaining sufficient sample numbers within resource constraints. The influence of various other factors on minimum population size requirements can be investigated through Mendel's Accountant. The effect of natural or artificial elimination of the least-fit individuals can be examined. While other forward-time population genetics simulators exist, Mendel's Accountant excels in ease of use, graphic output, biological realism and applicability to problems of genetic resource preservation. It has only recently been made publicly available, and we welcome suggestions for improvements and reports of experiences with its use in a teaching or research context. Mendel's accountant can be downloaded free at mendelsaccountant.info .

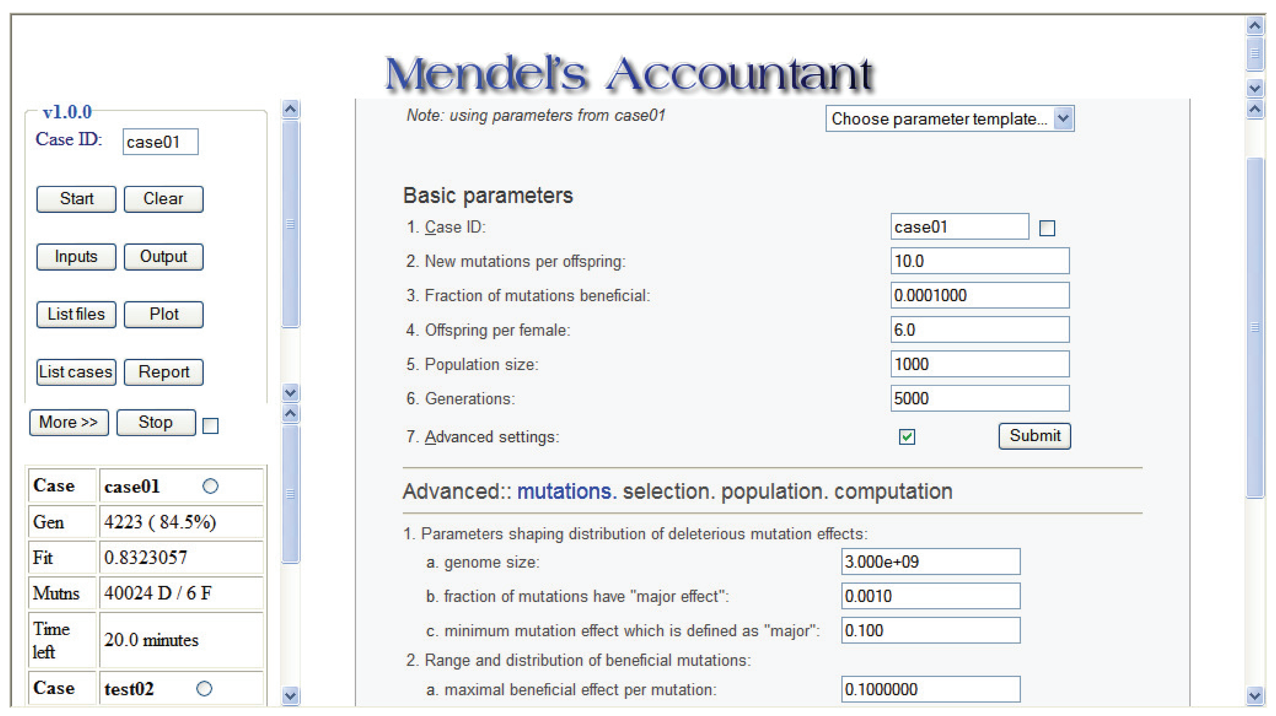
Question: Can Mendel's accountant be used to assist in evaluating seed bank issues?

Test Case: How severe is expected allele loss in small populations over a number of cycles of reproduction?

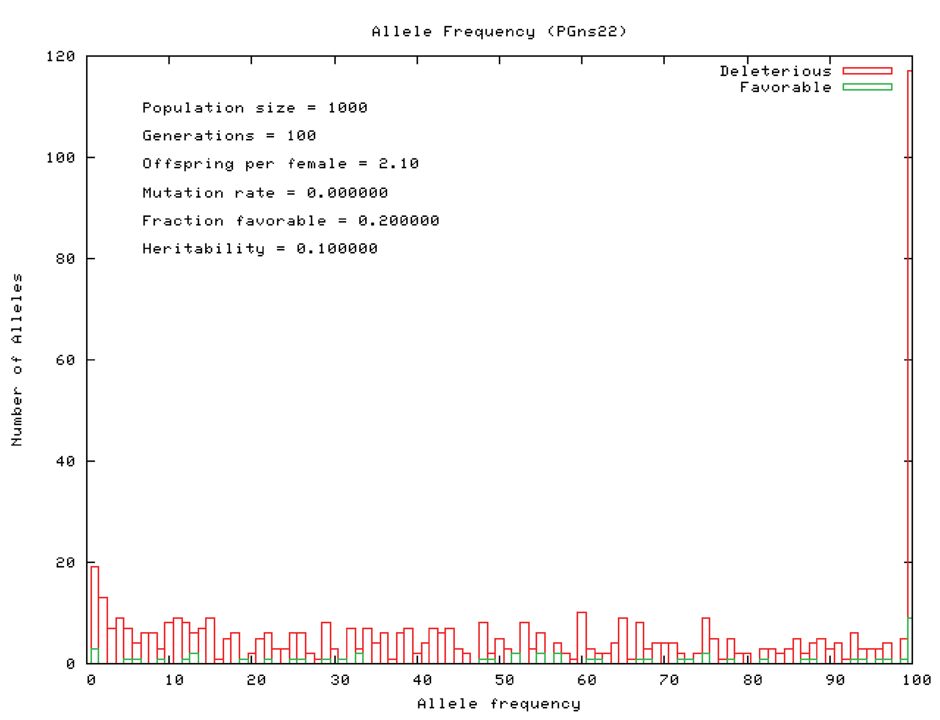
Introduction: Genetic collections

The presumption is that each sample may have rare or unique alleles that may be important to future crop improvement. Thus, allele loss should be minimized by using the maximum feasible population size, the minimum number of generations of reproduction, and by reducing selection pressure as much as possible. The reason for the latter is that the environment of reproduction presumably favors different alleles than may be most useful under future conditions. Because of sample numbers in the thousands or tens of thousands, curators have to balance frequency of reproduction, number of seed stored, number and size of user distributions, and potential for valuable allele loss through drift and unintentional selection.

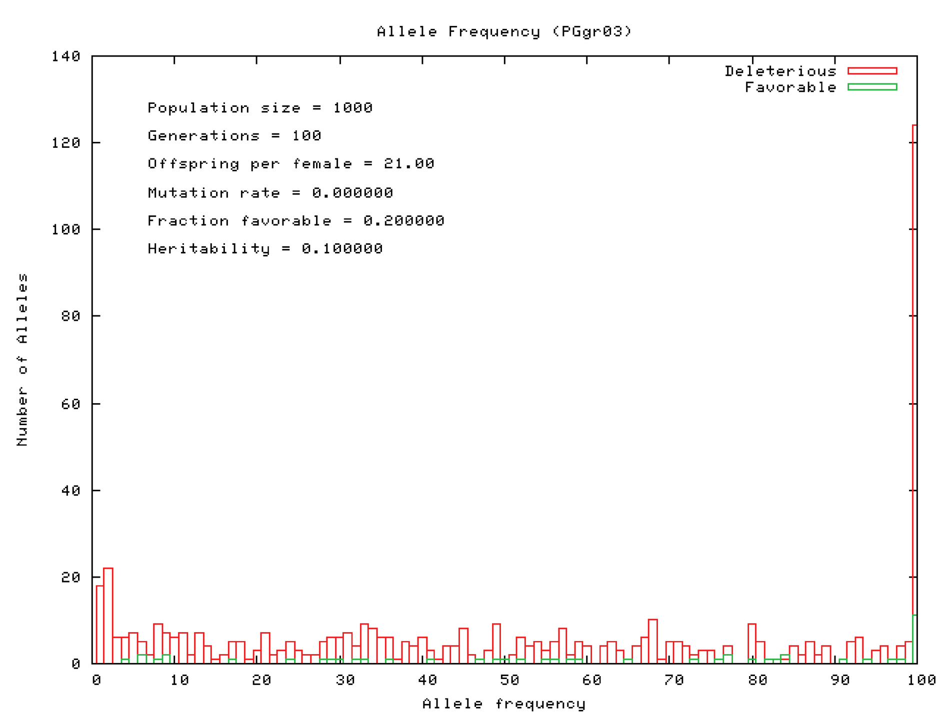
Introduction: Mendel's Accountant



- A forward-time population genetics simulator
- Simulates fitness over time as influenced by a number of different factors
- Is programmed for maximum biological realism
- Includes different fitness functions (probability selection, truncation selection)
- Includes environmental noise at user-specified levels
- Has a graphical user interface, and outputs results as graphs and data files.



a.



b.

Allele distributions at the beginning (a) and the end (b) of 100 generations of reproduction were almost identical. The size of the reproducing population was 100 (after 90 % random elimination).

Evaluation of small population size on allele loss:

Method:

I. Created a virtual population with numerous alleles of various fitness effects and various frequencies.
  a. A population was created with a large number of single copy mutants (positive and negative).
  b. This population reproduced by random mating without selection for 500 generations, resulting in the full range of allele frequencies for different alleles.

II. The virtual population was then reproduced through 100 cycles, with 100 parents/cycle.
  a. 20 offspring/female (1/2 of individuals arbitrarily designated as female).
  b. Random population loss was set at 0.9, to represent distribution of the seed between reproduction cycles, and other random losses.

Input values:

0 new mutations (many mutations present in the starting population created for this evaluation)

Exponential (Weibull function) distribution of mutation effects

All alleles co-dominant

No selfing

Heritability = 0.1, Non-scaling noise = 0.1 (together they create a heritability < 0.1)

20 offspring/fem., 0.90 random death (= 2 offspring/female, no selection)

Probability selection

Results:

With 100 parents/generation, and 100 generations of reproduction, in the absence of selection, allele loss was minimal.

1. There was almost no change in the number of deleterious alleles/individual (~3270) nor of favorable alleles/ind (800)
2. 15 of the 588 different favorable alleles were lost (2.6%)
3. 15 of the 2218 deleterious alleles were lost (0.7%)
4. With minimal selection (5% elimination, probability selection, h^2=0.02), deleterious allele loss was considerably greater (3.8%)

Conclusion:

Mendel's Accountant shows that loss of alleles due to drift is relatively small even in small population sizes (100) over the course of 100 generations in the absence of selection. However, even very mild selection substantially increases loss of alleles with negative adaptive value in the seed production environment.

Further analyses needed:

Evaluate population sizes < 100

Evaluate a wide range of input values, including selection intensity, and rate of new mutations.

Use the above to suggest the minimum appropriate population size for differing conditions.

Discussion:

The present simulation suggests that the most critical factor in preventing allele loss is the absence of selection.

Selection should be minimized by optimizing both growing conditions and storage conditions. This will provide each genotype has the maximum opportunity for reproduction.

The population should be reconstituted with equal numbers of seed from each parent, to the extent feasible, in order to:

- Minimize the selective advantage of more vigorous individuals in the current environment
- Preserve the original gene frequencies as much as possible.

References

J. Sanford, J. Baumgardner, W. Brewer, P. Gibson, and W. Remine. Mendel's Accountant: A biologically realistic forward-time population genetics program. SCPE. 8(2), July 2007, pp. 147-165.

J. Sanford, J. Baumgardner, W. Brewer, P. Gibson, and W. Remine. Using computer simulation to understand mutation accumulation dynamics and genetic load, in Y. Shi et al. (eds.), ICCS 2007, Part II, LNCS 4488, Springer-Verlag, Berlin, Heidelberg, pp. 386-392.

The authors encourage others to consider Mendel's Accountant as a research tool. It is available free at mendelsaccountant.info .