Garden of Inheritance

A Guide to Mendel's Pea Plant Simulator

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Welcome to Garden of Inheritance

Welcome to the Garden of Inheritance, a genetics simulation that recreates Johan Gregor Mendel's groundbreaking pea plant experiments from 1856-1863. This simulator allows you to explore the fundamental principles of heredity through hands-on breeding experiments, discover Mendelian laws, and understand how traits pass from generation to generation.

Whether you're a student learning genetics for the first time or an educator looking for an interactive teaching tool, this guide will help you master the simulator and unlock the secrets of inheritance.

For his work, Mendel is sometimes referred to as the father of genetics. To appreciate Mendel's work in its historical context and its consequences for the 20th century, particular the rise of eugenics, the first chapters of the following book are highly recommended: *The Gene: An Intimate History by Siddhartha Mukherjee*.

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1. Overview of the Simulator

What is Garden of Inheritance?

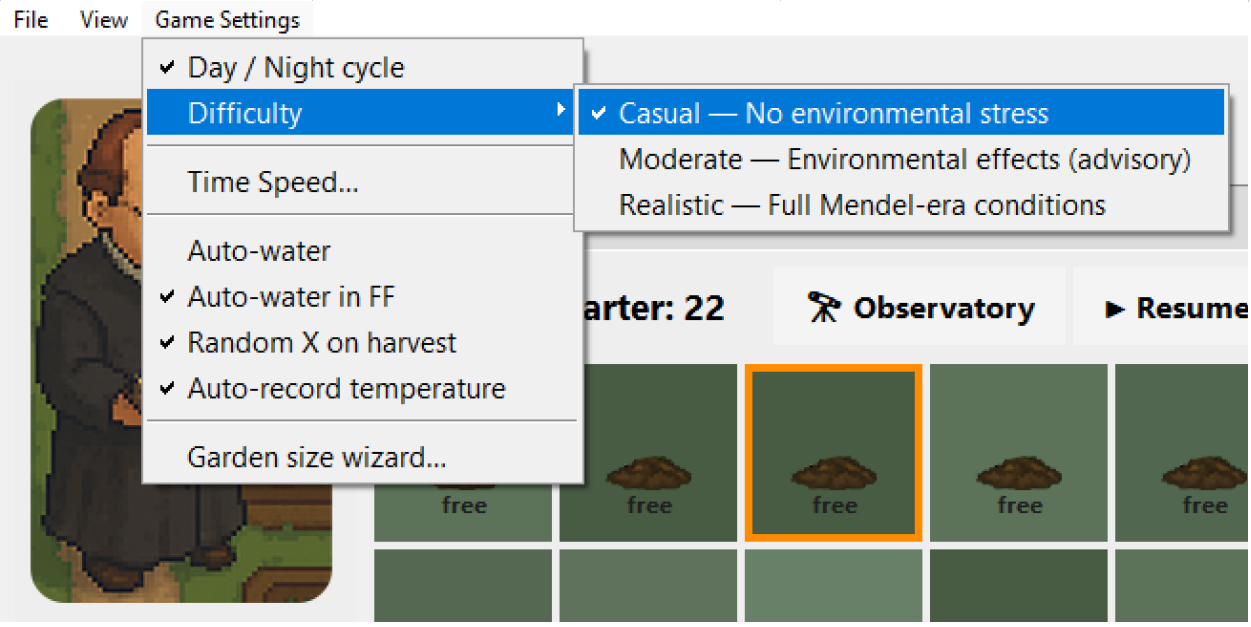
Garden of Inheritance is a comprehensive genetics simulator that recreates the extraordinary work done by an Austrian friar, Gregor Mendel, in his monastery garden (now Brno, Czech Republic) during the 19th century. The simulation features:

- Interactive garden grid where you plant, grow, and breed pea plants
- Realistic plant lifecycles with multiple growth stages
- Seven heritable traits following Mendelian genetics
- Environmental simulation including weather, temperature, and seasons
- Breeding tools for controlled pollination and crossbreeding
- Trait Inheritance Explorer (TIE) for tracking plant lineages

Game Modes and Difficulty

The simulator offers three difficulty modes that affect plant growth speed and lifecycle and that can be changes under Game Settings > Difficulty:

Mode	Growth Speed	Best For
Casual	Fast (30-35 days to maturity)	Quick experimentation and learning
Moderate	Medium (55 days to maturity)	Balanced gameplay
Realistic	Slow (85+ days to maturity)	Historical accuracy, slightly more tricky

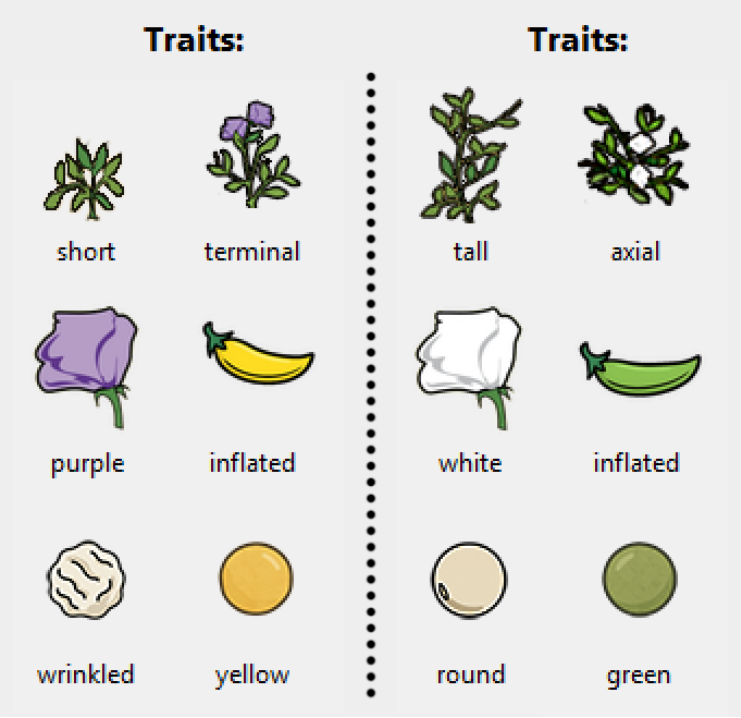


2. Core Mechanisms

The Seven Traits

Each pea plant in the simulation has seven traits that follow Mendelian inheritance patterns. These traits were chosen to match Mendel's original experiments:

Trait	Possible Values	Visible at Stage
Plant Height	Tall / Dwarf	Stage 3 (Young plant)
Flower Position	Axial / Terminal	Stage 5 (Flowering)
Flower Color	Purple / White	Stage 5 (Flowering)
Pod Color	Green / Yellow	Stage 6 (Pod development)
Pod Shape	Inflated / Constricted	Stage 7 (Mature seeds)
Seed Shape	Round / Wrinkled	Stage 7 (Mature seeds)
Seed Color	Yellow / Green	Stage 7 (Mature seeds)

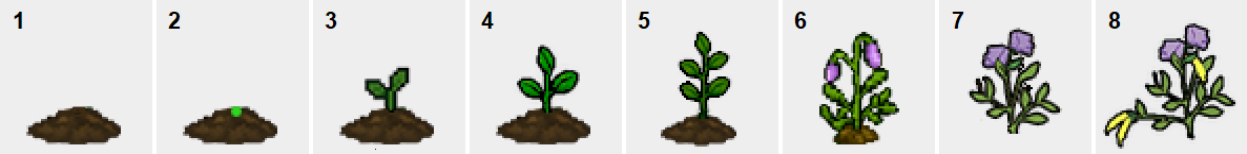


Traits are revealed progressively as plants grow. You cannot see seed traits until the plant reaches full maturity with developed pods.

Growth Stages

Plants progress through eight distinct stages:

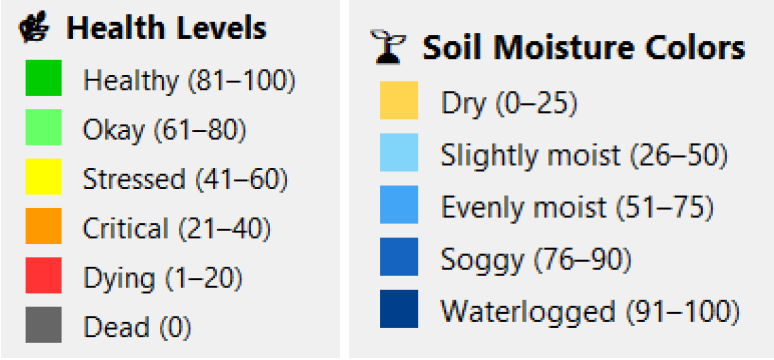
1. Empty plot
2. Seed
3. Young Seedling
4. Advanced Seedling
5. Young plant
6. Budding
7. Flowering
8. Pod development and over time Mature Seeds



Water and Health System

Each plant has water and health levels that determine survival:

- Water level: 0-100. Optimal range is 40-70.
- Health: 0-100. Plants die when health reaches 0.
- Water evaporates over time, faster in hot or sunny weather.
- Rain automatically adds water to all plants.
- Too little water (<20) or too much water (>95) damages health.
- Watering at noon or afternoon causes stress damage.



Time and Weather

The simulation starts on April 1, 1856 (Mendel's time). Time progresses in two ways:

- Hourly: Each hour, temperature changes and plants lose some water.
- Daily: At midnight, plants age by one day and advance growth.
- Fast-forward: Skip multiple days at once, useful for growing plants quickly.

Weather affects water evaporation and plant health. Watch for sunny days (rapid water loss) and rainy days (automatic watering).

Reproduction Mechanics

Self-Pollination

Pea plants naturally self-pollinate. If you do nothing, flowering plants will fertilize themselves and produce seeds with the same genetic makeup as the parent. This creates the F1 generation.

Emasculation

To perform controlled crosses, you can emasculate plants during the budding stage (Stage 4) or early flowering (Stage 5). This removes the anthers (pollen-producing organs) and prevents self-pollination. Emasculated plants show an "E" indicator and cannot produce their own pollen.

Cross-Pollination

After emasculation, you can collect pollen from another plant (Stage 5, health ≥70) and apply it to the emasculated plant. This creates a hybrid offspring combining traits from both parents. Cross-pollinated plants show a "P"; indicator.

Pollen Collection and Expiration

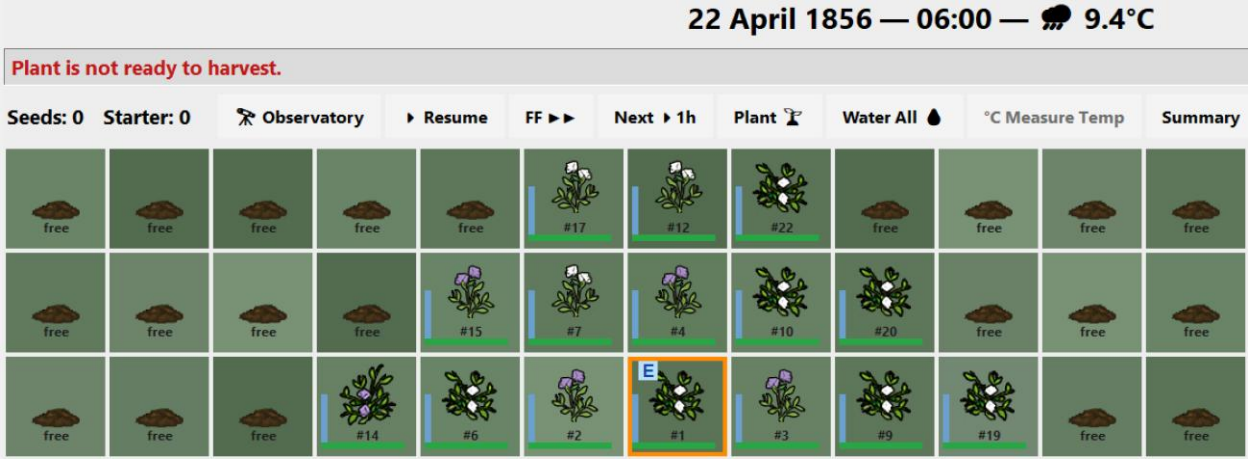
Pollen can be collected during the flowering stage. Each pollen sample has an expiration date (typically 1 day after collection). Expired pollen cannot be used for pollination. Plan your crosses carefully.

3. Getting Started: Basic Operations

Interface Overview

The main interface consists of:

- Garden grid: Your planting area with individual tile plots
- Header bar: Shows date, time, weather, and temperature
- Selection panel: Displays selected plant's details and traits
- Control buttons: Time controls, watering, Summar (inventory)
- Status bar: Notifications and messages appear here in red



Essential Controls

Press "H" for the help menu showing all keyboard shortcuts.

- Left-click a plant: Select it and press "I" to view details
- Right-click an empty plot: Opens planting menu
- Right-click a plant: Opens action menu (water, emasculate, pollinate, etc.)
- Time controls: Play/Pause (Spacebar), Next Hour, Fast Forward (F)
- Watering: Water All (W), Smart Water (automatically skips well-watered plants)

Planting Seeds

There are several ways to plant seeds:

1. Single seed: Right-click an empty plot → Plant → Choose a seed from inventory
2. Seed group: Right-click → Plant Group → Seeds are planted in a pattern around the plot
3. Starter seeds (F0): Begin with these to establish your first generation

Managing Your Garden

- Remove plants: Right-click a plant → Remove, or Remove All to clear the garden
- View inventory: Click Summary button
- Open Trait Inheritance Explorer: View your plant records and lineages
- Save/Load: Save your garden progress and reload later

4. Step-by-Step Tutorial: Growing Your First Plant

This tutorial will guide you through growing your first pea plant from seed to harvest.

Step 1: Plant a Starter Seed

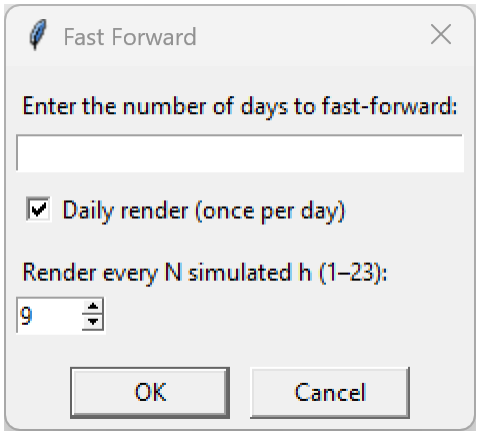
1. Right-click on any empty plot in the garden grid
2. Select “Plant Group” → “Starter Seeds”
3. Several seeds will be planted in a pattern around your selected plot

The plot will now show a seed icon (Stage 1). Your plants have begun growing!

Step 2: Fast-Forward to Maturity

Instead of watching plants grow in real-time, use Fast Forward:

1. Press “F” or click the Fast Forward button
2. Enter 35 days (for Casual mode) or more for slower modes
3. **Daily render:** When checked, the simulation renders only once per simulated day (every 24 hours), which provides the best performance.
   When unchecked, you can use the 'Render every N simulated h' setting below to control update frequency. Higher hour intervals (e.g., 15-23) render less frequently and run faster, while lower intervals (e.g., 1-3) let you watch progress more closely but run slower.
4. Click OK



The simulator will automatically water plants during fast-forward. Watch the plants grow through all stages until they reach Stage 7 (Mature seeds).

Step 3: Observe Traits

Once plants reach maturity, click on different plants to observe their traits:

- Notice the flower colors (purple or white)
- Check plant height (tall or dwarf)
- Look at pod and seed characteristics

Step 4: Harvest Seeds

1. Select a mature plant (Stage 7) with traits you want to preserve
   a. **Harves a single Pod**: Press “S” or right-click → Harvest Seeds
   b. **Harvest all Pods:** Press “Shift + S” or right-click → Harves ALL Seeds
2. Each harvest collects seeds from one pod (~5-7 seeds)
3. Harvest multiple times from the same plant to collect more seeds

A notification will appear showing how many seeds you harvested. These seeds are now in your inventory and can be planted to grow the next generation.

Step 5: Plant the Next Generation

1. Right-click → Remove All to clear the garden (Optional)
2. Right-click an empty plot → Plant Group
3. Select your harvested seeds from the list
4. Press “Play” or “Space” or “Fast-forward” again to see the F1 generation grow

Congratulations! You’ve completed the basic growth cycle. Now you can start exploring genetics through controlled crosses.

5. Advanced Techniques: Controlled Crosses

To discover Mendelian laws, you need to perform controlled crosses where you choose both parents. This requires emasculation and cross-pollination.

Step-by-Step: Performing a Controlled Cross

Phase 1: Prepare Your Parent Plants

1. Plant two groups of F0 starter seeds with different traits (e.g., purple flowers vs white flowers)
2. Advance time but only to reach the budding stage (Stage 4)
3. Do miss the stage or plants will start to self-pollinate!

Note: The F0 starter seeds come with random traits. Plants showing recessive traits (white flowers, dwarf height, wrinkled seeds, etc.) are always homozygous and breed true. Plants showing dominant traits may be either homozygous or heterozygous. Grow them to maturity, harvest at least a dozen seeds, and observe the F1 generation to determine their genetic makeup. If all F1 offspring show the dominant trait, the parent was likely homozygous; if F1 shows a 3:1 ratio, the parent was heterozygous.

Phase 2: Emasculate the Mother Plants

1. Select plants you want to use as mothers (will receive pollen)
2. Right-click → Emasculate (or press “E”)
3. An interactive dialog appears - click on each of the 10 yellow anthers to remove them
4. An “E” indicator will appear on successfully emasculated plants

Emasculated plants cannot produce pollen or self-pollinate. They will remain at Stage 5 until pollinated.

Important: Timing is critical. You must emasculate during Stage 4 (budding) or very early Stage 5 (flowering). Missing this window means plants will self-pollinate and ruin your controlled cross.

Phase 3: Grow to Flowering and Collect Pollen

1. Wait a few more days until plants reach flowering stage (Stage 5)
2. Select a non-emasculated plant (father) with high health (≥70)
3. Right-click → Collect Pollen (or press “C”
4. Pollen collection is only available during morning or noon

The pollen is now stored in your inventory with an expiration date. Check the inventory (Summary) to see your collected pollen.

Phase 4: Pollinate the Mother Plants

1. Select an emasculated plant (mother)
2. Right-click → Pollinate (or press “P”
3. Choose the pollen you collected from the inventory popup
4. Click “Use” to apply the pollen
5. An interactive dialog appears - click on the stigma, located at the tip of the pistil, the central female reproductive organ, that connects
6. A “P” indicator confirms successful pollination

The pollinated plant will now develop pods with hybrid seeds combining traits from both parents.

Phase 5: Harvest and Analyze Hybrid Seeds

7. Wait until crossed plants reach maturity (Stage 7)
8. Harvest all seeds from the crossed pods
9. Plant these F1 hybrid seeds in a new generation
10. Grow them to maturity and observe the traits
11. You should notice patterns in how traits are inherited

Tips for Successful Crosses

- Always emasculate before or at the very start of flowering
- Use fresh pollen
- Harvest many seeds from each cross to get statistically significant results
- Use the Trait Inheritance Explorer to see which parents were used for each cross, to track lineages and analyze inheritance patterns

6. Discovering the Mendelian Laws

The simulator tracks your experiments and can detect when you’ve demonstrated the three fundamental Mendelian laws of inheritance.

Law of Dominance

What it means: In a heterozygous organism, one allele (dominant) masks the expression of another allele (recessive).

How to discover it:

1. Cross two pure-breeding plants with contrasting traits (e.g., purple flower × white flower)
2. Grow the next generation
3. Observe that ALL plants of this generation show only one trait (the dominant one) by using the Trait Inheritance Explorer.
4. The recessive trait appears to have disappeared

Example: All F1 plants from a purple × white cross will have purple flowers, showing that purple is dominant over white.

Law of Segregation

What it means: During gamete formation, paired alleles separate so each gamete receives only one allele for each trait.

How to discover it:

1. Take F1 hybrid plants (from the dominance experiment)
2. Allow them to self-pollinate (or cross two F1 plants)
3. Grow the F2 generation
4. Count the traits in F2 offspring
5. Observe approximately a 3:1 ratio (dominant:recessive)

Example: From F1 purple flowers, the F2 generation shows about 75% purple and 25% white flowers (3:1 ratio).

Law of Independent Assortment

What it means: Genes for different traits are inherited independently of each other (assuming they're on different chromosomes).

How to discover it:

6. Cross plants differing in TWO traits (e.g., purple/tall × white/dwarf)
7. Grow the next generation (should show both dominant traits)
8. Self-pollinate F1 plants to produce F2
9. Count trait combinations in F2
10. Observe approximately a 9:3:3:1 ratio for the four possible combinations

Example: F2 from a two-trait cross should show 9 purple-tall : 3 purple-dwarf : 3 white-tall : 1 white-dwarf.

Using the Trait Inheritance Explorer

The simulator includes a powerful analysis tool to help discover laws:

1. Right-click on a plant → Inspect
2. View the lineage tree showing parents and offspring
3. Select different traits to analyze their inheritance patterns
4. Check the ratio display (bottom right) to see phenotype ratios
5. Export plants that demonstrate laws to credit your discoveries

Important: Do not reveal the genotype (A/A, A/a, a/a) before unlocking laws! Looking at genotypes disqualifies those plants from law discovery. Work only with observed traits (phenotypes).

7. Tips and Strategies

Efficient Garden Management

- One can use Auto-water (automatically waters only plants that need it) from the “Game Settings” instead of watering manually
- Fast Forward handles watering automatically, making it ideal for growing large batches
- Group similar crosses together for easier tracking and analysis

Breeding Strategies

- Start with single-trait crosses before attempting multi-trait experiments
- Harvest recessive plants sparingly (e.g. white-flowered) - use them strategically as recessive markers
- For the **Law of Dominance**, you need at least 16 plants derived from a cross between true-breeding parents, all showing the same dominant trait
- **For the Law of Segregation**, grow at least 65 plants (F2 after the parent cross) to get statistically reliable 3:1 ratios (requires 73-85% dominant phenotype)
- For the **Law of Independent Assortment**, you need at least 80 dihybrid plants (F2 after the parent cross) analyzing two traits simultaneously (must pass chi-square test for 9:3:3:1 ratio)

Avoiding Common Mistakes

- Don’t miss Budding stage if you intend to emasculate
- You can’t harvest seeds from emasculated, non-pollinated plants - they won’t have any
- Don’t reveal genotypes before discovering laws - it disqualifies the plants

8. Keyboard Shortcuts Reference

Press “H” in the simulator to view all shortcuts. Here are the most important ones:

Key	Action
H	Show help / keyboard shortcuts
Spacebar	Play / Pause time
P	Play / Pause time (same as Spacebar)
F	Fast Forward dialog
w (lowercase)	Water selected plant
W (Shift+W)	Water all plants
s (lowercase)	Harvest seeds from one pod of selected plant
S (Shift+S)	Harvest all seeds from selected plant
E	Emasculate selected plant
C	Collect pollen from selected plant
O	Pollinate selected plant with stored pollen
I	Inspect selected plant
L or N	Open inventory summary
Shift + O	Open inventory summary (Pollen tab)

Final Remarks

You now have all the knowledge needed to explore Mendelian genetics in the Garden of Inheritance. Start with simple crosses, observe patterns, and gradually work toward discovering the three fundamental laws of heredity.

Remember: genetics is about patience and careful observation. Take your time, look at your records, and enjoy the process of scientific discovery. Mendel spent a decade breeding thousands of pea plants in his monastery garden. Now, you too can unlock the secrets of inheritance through systematic experimentation in a day or two.

Happy gardening, and may your experiments reveal the beautiful patterns of heredity!