Bee Math

Six numbers — 8 / 9 / 10 and 16 / 21 / 24 — generate most of what follows. Learn the development table and you can predict what is happening inside a hive without opening it.

Bee math matters because a hive answers questions on its own schedule, not on ours. A colony is a slow system watched through a narrow window: you open it for ten minutes every week or two, and almost everything you want to know is either hidden under cappings or three weeks in the past. The numbers close that gap. They let you date an egg, predict a swarm before the cell is capped, tell a queenless colony from one that is simply between queens, and know whether a mite count is survivable or already fatal to bees not yet born. Without them you are reacting to what you can see, which is always the consequence of a decision the colony made weeks ago; with them you are working ahead of the hive rather than behind it. The arithmetic is also honest in a way that impressions are not. A frame can look strong and a yard can feel healthy while the counts say otherwise, and the beekeeper who checks is the one whose colonies are alive in March.

The development table

Everything else is derived from these six numbers: capped on day 8 / 9 / 10, emerged on day 16 / 21 / 24.

Stage	Queen	Worker	Drone
Egg hatches	Day 3	Day 3	Day 3
Cell capped	Day 8	Day 9	Day 10
Emerges	Day 16	Day 21	Day 24

What falls out of it:

Derived number	Value	Why
Eggs present, so the queen laid within	3 days	Eggs hatch on day 3
Open brood present, so the queen laid within	9 days	Worker cells cap on day 9
Capped queen cell, so a swarm is imminent	Day 8 (plus or minus 1)	A prime swarm usually leaves at or just before capping
Safe inspection interval in swarm season	7 days	An egg laid the day after you close up is capped on day 8; nine days is already too late
Brood-free interval after caging the queen	24 days	The last drone egg laid on day 0 emerges on day 24
Capped brood still emerging after queen loss	12 days	The last egg laid caps on day 9 and emerges on day 21

Queen math

Egg to laying queen is about 28 days, so do not judge a walk-away split before four weeks.

Number	Value
Emergence to first orientation flight	5–6 days
Emergence to mating flights	5–10 days, weather permitting
Emergence to first eggs	about 2 weeks (10–17 days)
Egg to laying queen, total	about 28 days (24–32)
Drones mated with	12–20 (range 7 to 20+)
Mating flights taken	1–3
Sperm stored in the spermatheca	5–7 million
Distance a queen flies to a drone congregation area	up to 2 miles
Drone flight to a drone congregation area	up to 5 miles
Drone sexual maturity	12–16 days after emergence
Peak laying rate	1,500–2,000 eggs per day
Productive queen life	1–2 years; she can live 3–5

Emergency cells run on a shorter clock. Workers select larvae no more than 3 days old, so the cell is capped around day 5 or 6 after queenlessness and emerges on day 11 or 12. That compressed larval period is why an emergency queen is often smaller.

Walk-away split arithmetic: 12 days to emergence plus about 14 days to laying is 26 to 30 days from split to a laying queen.

Population math

Population settles at the laying rate multiplied by worker lifespan, and it takes three weeks to show.

Number	Value
Bees per pound	about 3,500
Deep frame fully covered, both sides	about 2,500 bees
Cells per deep frame	6,600–7,000
Peak summer colony	50,000–60,000
Overwintering cluster	10,000–20,000
Frame of capped brood to frames of bees	1 to 2 or 3
Summer worker lifespan	4–6 weeks
Winter worker lifespan	4–6 months
Drone lifespan	4–8 weeks

The equilibrium equation:

$$Population = eggs\ per\ day \times worker\ lifespan\ in\ days$$

At 1,500 eggs a day and a 42-day lifespan that is about 63,000 bees at steady state. Halve the laying rate and the colony halves over roughly six weeks, not overnight. A failing queen in April shows up as a weak colony in May, and a mid-June supersedure costs the late flow.

The same equation runs backward. There is a 21-day lag between anything that stops the queen and the drop in foragers, so the colony in front of you was laid three weeks ago.

The worker task calendar

A worker spends her first three weeks inside the hive, so a colony needs three weeks of brood rearing before it gains one new forager.

Days	Job
1–2	Cell cleaning
3–11	Nursing, with the hypopharyngeal glands active
12–17	Wax, comb building, receiving nectar
18–21	Guarding
21 onward	Foraging until death

Nurse bees can revert to foraging under stress and foragers can revert to nursing, but both shifts cost lifespan.

Foraging math

A 2-mile foraging radius puts roughly 8,000 acres in reach of every hive.

Number	Value
Effective foraging radius	2–3 miles, up to 5 or 6
Area within a 2-mile radius	about 8,000 acres
Flight speed	about 15 mph
Trips per forager per day	10–15
Flowers per trip	50–100
Nectar load	40–50 mg, about half her weight
Pollen load, both baskets	15–20 mg
Bee weight	90–100 mg
Honey produced per bee, lifetime	about one twelfth of a teaspoon
Flower visits per pound of honey	about 2 million
Miles flown per pound of honey	about 55,000

Nectar runs 20 to 40 percent sugar and honey runs 82 to 83 percent. That is roughly 3 to 4 pounds of nectar per pound of honey at 40 percent sugar, and closer to 7 or 8 pounds at 20 percent. A light-sugar flow can look busy and still not fill a super.

Wax costs 6 to 8 pounds of honey per pound of wax. Ten deep frames of foundation ask the colony for roughly 10 to 16 pounds of honey, which is why a box of foundation is an expensive ask during a weak flow.

Weight and volume math

A deep frame of capped honey runs 7 to 8 pounds, which is how you estimate a harvest before you ever extract.

Number	Value
Deep frame full of capped honey	7–8 lb
Medium frame	5–6 lb
Shallow frame	3–4 lb
Deep super, 10 frames full	80–90 lb
Medium super, 10 frames full	50–60 lb
Shallow super	35–40 lb
Honey per gallon	12 lb
5-gallon bucket	60 lb
Honey per pint	1.42 lb
Deep box interior volume	about 42 L (1.5 cu ft)

The supering rule is 7 of 10: add the next box when 7 frames are drawn and worked. Waiting for 10 invites swarming, and adding at 3 invites chilled brood and wax moths.

Harvest on two numbers. Extract at 80 percent capped or better, and hold moisture at 18.6 percent or lower, which is roughly 81 to 82 Brix. Above that it ferments.

Varroa math

Mites double every 3 to 4 weeks during brood rearing, so 50 mites in March is about 3,200 by September.

Number	Value
Alcohol wash sample	half a cup, about 300 bees
Mid-season treatment threshold	3 mites per 100 bees (9 in a 300-bee sample)
Pre-winter threshold	1–2 per 100
Economic injury level	about 5 per 100
Foundress enters the cell before capping	15–20 h for worker, 40–50 h for drone
First mite egg after capping	about 70 h, then one every 30 h
Viable daughters per worker cell	1.3–1.5
Viable daughters per drone cell	2.2–2.6
Drone brood attractiveness	8 to 12 times worker brood
Population doubling time in brood season	3–4 weeks

That compounding is the whole argument for sampling early and by the numbers rather than by eye. You cannot see a 1 percent infestation, and by the time you can see mites riding on bees you are past 10 percent.

Late-season counts matter most because the bees that carry a colony through winter are raised in August and September. Mites feeding on those pupae produce short-lived winter bees, so a clean October count on a colony that was dirty in August is a colony that has already lost its winter bees.

Brood break arithmetic: 24 days of caging makes every mite phoretic and exposed. A 9-day break only clears capped brood and leaves mites in cells.

Thermal math

The brood nest is held at 93 to 95 degrees F within about half a degree, which is the tightest number in the hive.

Number	Value (°F)
Brood nest temperature	93–95 (34–35 °C), held within about 0.5°
Cluster forms at	about 57 (14 °C)
Cluster core, broodless	68–80
Cluster mantle minimum	46–48
Minimum flight temperature	50–55
Wax secretion requires	91–97
Wax melts	143–147
Fanning begins at internal	about 95

Two consequences. Brood held below the low 90s for long develops poorly, which is the real cost of a long inspection on a cool morning. And a cluster cannot move laterally to food below about 50 degrees, which is how a colony starves with honey three inches away.

Stores and feeding math

A colony eats 400 to 500 pounds of honey a year, of which winter stores are only the visible part.

Number	Value
Winter stores needed, Southeast	40–60 lb
Winter stores, northern climates	60–90 lb
Annual colony honey consumption	400–500 lb
Annual pollen consumption	50–100 lb
Honey to raise one worker	about 130 mg
Pollen to raise one worker	120–145 mg
1:1 syrup	about 50 percent sugar; matches nectar and stimulates brood

Number	Value
2:1 syrup	fall storage; less water to evaporate
1 gallon of 2:1 syrup	about 12 lb, yields about 7 lb stored

Pollen is the number most people skip. Raising 1,000 workers takes roughly a third of a pound of it, so a colony building to 60,000 bees over a season moves an enormous volume. A pollen shortage caps brood rearing no matter how much syrup is on the hive.

Swarm math

The 8-day clock from queen cell egg to departure is the most consequential number in spring management.

Number	Value
Swarm preparation before departure	2–4 weeks
Queen cell egg to departure	8–9 days
Workers leaving with a prime swarm	about 60 percent (50–70)
Honey carried per swarm bee	about 40 mg, three days of fuel
First cluster from the parent hive	50–100 ft
Final nest site distance	0.3–1 mile typical
Scout bees	about 5 percent of the swarm
Quorum to commit to a site	15–20 scouts at the site
Preferred cavity volume	about 40 L, roughly one deep
Preferred entrance	about 2 sq in, low on the cavity, 10 ft or more up
Afterswarm, days after the prime	8–10 days, with a virgin queen

That 8-day clock is why inspections run on 7 days in swarm season, and why a capped cell means the decision has already been made for you.

Equipment math

Bee space is a quarter inch to three eighths, and that one range explains most of the hive body's design.

Number	Value
Bee space	1/4 to 3/8 in (6–9 mm); 5/16 in ideal
Frame spacing, center to center	1 3/8 in (35 mm)
Worker cell diameter	5.2–5.4 mm
Drone cell diameter	6.2–6.4 mm
Package weight to bees	3 lb is about 10,500 bees

Anything under a quarter inch gets propolized shut and anything over three eighths gets burr comb.

The ten worth memorizing cold

1. 3 and 9; 8 / 9 / 10; 16 / 21 / 24
2. 7-day inspections in swarm season
3. About 28 days from split to a laying queen
4. 3,500 bees per pound, 2,500 per deep frame, 1 frame of brood equals 2 to 3 frames of bees
5. A 300-bee sample; 3 mites per 100 mid-season, 1 to 2 going into winter
6. 95 °F brood nest, 57 °F cluster, 50 °F flight floor
7. 18.6 percent moisture, 80 percent capped, 12 lb per gallon
8. 1 lb of wax costs 6 to 8 lb of honey
9. Population equals laying rate times lifespan, with a 21-day lag
10. Mites double every 3 to 4 weeks