SAVING THE COMMONS SIMULATION

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OVERVIEW

The Commons Simulation is an in-class role-play game utilized to demonstrate the outcome of individual incentives in situations where property rights are poorly defined or are allocated as a common good. Garrett Hardin coined the term, Tragedy of the Commons, in his seminal article of the same name (Hardin, 1968). The simulation is particularly effective for laying an experiential foundation for discussions of market functioning, environmental degradation, and the basics of environmental economics. It can be used to address both the problems that arise when markets systems meet common property resources (CPR), as well as the set of possible solutions to managing such resources. Perhaps most importantly, it can get students to rethink singular perspectives on the efficacy of markets for allocating scarce resources in certain contexts. In more than 15 years using the simulation it has never failed to engage students, make a point about the outcomes of markets under poorly defined property rights regimes, and serve as a foundation for discussions throughout courses. It is often a perfect start to a course on sustainable enterprise because it serves as a great icebreaker exercise while providing an unforgettable foundation of knowledge about market dynamics for common goods.

The simulation can accommodate 5-8 teams of 2-5 players per team, and takes approximately 2.5 hours to complete. Published by Fryxell and Dooley (1997), the simulation builds from the work of Hardin (1968). It places students in the role of the management team for a manufacturing facility and asks them to make decisions with relevant environmental and financial implications. Students are told that their goal is to achieve the highest financial return possible and that the two teams with the highest scores will win (we bring candy for the top two teams to insure their motivation). The manufacturing facilities draw water from, and release toxic pollutants into, a nearby lake. The government does not regulate these activities and no property rights are allocated to the lake (it is a typical un-regulated common good). Throughout the sixteen or more rounds of decisions, teams confidentially decide whether to continue to degrade the lake by releasing pollutants or to limit pollution by treating wastewater before discharge. The financial repercussions of these two choices are dependent on the decisions of other teams and on the quality of the lake water. As the quality of the water degrades from teams who choose not to treat their wastes, payoffs for all choices decline. The payoff matrices resembles a prisoner’s dilemma situation, whereby the collective outcome is maximized when all teams choose to cooperate by limiting pollution because payoffs are higher when the lake quality is higher; but individual returns are maximized when teams "defect" by releasing pollutants. These "free-riders" don't incur additional costs for water treatment and therefore have higher profits, but the lake degrades every time a team chooses not to treat their wastewater. Teams that initially choose to treat their wastes observe that the polluting teams are experiencing higher returns, and some inevitably choose to start polluting the lake as well. Soon, the lake degrades rapidly and payoffs decline for all teams.

Starting in round 8 of the game, teams can make additional choices. A team can choose to reward the team who has polluted the least over the course of the game, but choosing this option is costly. This is the "green award" for the game and we have seen some teams do well later in the game by rewarding themselves with the green award. Similarly, a team can choose to attempt to enforce fines on defecting teams, but this is also costly to the enforcing team, and enforcement rates are low (in other words, defecting teams often don't get caught and don't have to pay a fine). The low enforcement rate and the cost of enforcement make it difficult for any individual team to change the direction of the game by choosing this option. In short, the rules of the game (the structure of payoffs and inability to consistently fine defectors) ensure that the strategy of polluting the lake almost always results in the best individual financial returns. Because the team with the best financial performance wins the game, students' competitive nature almost inevitably results in the degradation of the lake and reduced financial performance for all.

But the game also provides further nuance, which enables the teams to collectively solve the tragedy of the commons by changing the rules of the game. This typically occurs during conferences between representatives from each team. During these conferences, instructors can encourage the students to begin resolving the commons problem through various institutional changes. But, from a pedagogical perspective, it is best to do this later in game, once some of the dynamics of the tragedy have played out. Conferences are scheduled in rounds 8, 12, 15, and 20. In the first conference (round 8), we typically try to get all the teams to agree to stop polluting the lake but discourage any formal changes to the rules (As President and convener of the conference, the instructor holds lots of power over the rules). If teams agree to stop polluting, the typical result is that one or more teams shirks on this verbal commitment, pollutes the lake, and achieves substantial financial gains. This enables an interesting (and sometimes passionate) discussion during the debriefing about the role of trust, and the lack of enforcement mechanisms in informal cooperative agreements. In the second team conference (round 12) we typically encourage a more effective solution, although ideally not too strict as to completely resolve the incentive problems in the game. Students often suggest solutions like having one team choose to enforce every round in an agreed upon order, or request a tax that will result in an increase in the enforcement rate when a team chooses to enforce. Sometimes, we will allow a tax be implemented to increase enforcement rates to a higher level. By the third team conference (round 15) the instructor should encourage ideas that solve the problem for good (i.e. a tax that pays for enforcement every round regardless of whether the any individual team chooses to enforce). Solving the game at this point enables the instructor to initiate a discussion during the debriefing about solutions to the commons problems. Once such an agreement is reached, we usually end the game within a few rounds. Typically, we play 16-20 rounds. We do not announce when the game will end until the round before it ends. Announcing the end of the game just prior to the final decision round enables a subsequent conversation about end game strategies and what is known in game theory as "backward unraveling."

We also conclude our debrief with a number relevant videos. Kahn Academy has two excellent and highly relevant videos, one on the prisoner's dilemma, and one on the Tragedy of the Commons. We also show a clip from the film, "A Beautiful Mind", which is about Nobel Prize winning economist, Jonathan Nash. We show the bar scene, entitled "Governing Dynamics", where Jon Nash has his epiphany about the "Nash

Equilibrium." We also sometimes listen to a speech by Elinor Ostrom, which provides ideas about solving the tragedy of the commons. All of these videos are typically available on YouTube.

The simulation is based on the work of Garret Hardin (1968) and was published by Fryxell, G. E., & Dooley, R. S. (1997).

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THE COMMONS SIMULATION

INSTRUCTOR'S MANUAL

The instructor should form plant management teams (between five and eight plant management teams are desirable. Eight is the maximum.). Each team is given a folder containing: the players manual; the profit /loss tally sheet; and colored squares representing the five choices (these are glued or stapled inside the folder). It should take about 10 minutes to read the manual, depending on the language mixes of the participants.

Instructors will need: an administrators log sheet; some device for tracking the quality of the lake; a set of payoff matrices; and dice. The first three items are described in more detail below.

Miscellaneous Advice:

Announce that the top two teams with more than 140 pazoozas win the game.

Announce that the top two teams above 140 also get candy or some other reward (I usually buy some candy bars prior to the game and show them to the class).

With a large number of participants, you may assign some students to serve as President of Kivulini, decision recorder, and lake quality monitor.

Announce that there will be at least 16 rounds of play (trials)

Announce the effect of choosing red on the lake quality. This can be either one or two decrements for each red chosen by the teams. For smaller numbers of teams (i.e. 6) I will decrement the lake quality by two for each red chosen. For 8 teams or for classes that are highly competitive in nature, we will typically decrement by only one for each red chosen.

Steps in the Simulation

1. Form teams (6-8 teams)
2. Handout players' manuals, tally sheets and folder with colored squares.
3. Students given time to read the manuals
4. Review the rules of the game using the Powerpoint slides. Answer any questions the students have.
5. Show the initial "0 Matrix" for payoffs and explain. Remind students that the game changes to other payoff matrices depending on the quality of the lake.
6. Students make first round decisions. Collect decisions confidentially from each team. Announce decisions and help students record scores. Only aggregate decisions are announced (for example, 4 reds and 3 blacks) in order to keep the identity of the choices confidential.
7. Adjust lake quality according to the number of reds played.
8. Continue with decision trials, following instructions on Administrator's score sheet. Blue and orange may be played after trial #7. If more than one team plays blue or orange, we typically only account for it once, but this is up to the discretion of the Administrator (i.e. we only roll the die once for enforcement regardless of how many blue's are played).
9. As listed on the Administator's score sheet, invite one participant from each team out into the hall for a conference. The goal is for them to solve the situation of the poor lake quality. But it is better that they do not solve it immediately. The typical result is that they all "agree" not to play red. But then they go back to play and someone plays red, and cooperation falls apart. In later trials in the game, the

administrator should allow them more leeway/encouragement to “solve” the problem, by allowing heavier fines, increasing enforcement, or setting up a better system.

10. Complete 16-20 rounds.
11. Debrief
    a. Tally team scores, ask them their strategies, and announce winners.
    b. Discuss the meaning of the game.

Administrators Log Sheet

After the teams have made their choices, the facilitator (or assistant) should visit each team and record their decision. On return to the front of the classroom, the totals should be announced and posted (on the board or flip chart) so that each team can calculate their payoff for that trial. After the first couple of trials, the facilitator (or assistant) should ensure that each plant team is completing the form correctly. If a team has chosen blue (fines) and another team(s) has chosen red in the same trail, die roll or double coin toss will be necessary to determine whether the polluting team(s) is caught (33% enforcement), identified and the fine is assessed. The selection of which team receives the “Green Prize” (when someone plays orange) should be made based upon prior performance (i.e. the team which has played red least often throughout the game). In the event of a tie, the decision may be settled with a coin toss (or other means). The nature of the Green Prize is left to the discretion of the facilitator. Ideally, it should be something green and flashy, but with little intrinsic value. We use a green ribbon or green tic tac candy.

Water Quality Index

Some device must be created to track water quality. We just draw a line on the board with ten increments per level, ranging from -4 to +4. Others use a board with holes drilled in it so that a peg, such as a golf tee, can indicate the current level of water quality. The simulation begins with the marker at the 0 level. As teams choose red (i.e., to continue polluting the lake water) the marker is moved down one or two units for each red chosen. Again, there are 10 increments per level. Every time the water quality reaches a new level a new matrix is used for payoffs.

The choice of how many units to move the marker down for each red choice depends on the number of plants and the type of participants. With six or fewer plants or highly competitive groups we use two units per red. With more plants, environmentally-oriented participants, or less competitive groups we use two. In typical play, the marker will initially move quickly downward into the -2 or -3 level. As each new region is reached, the new payoff matrix is shown to the students prior to the new trial.

Factories don’t make the water any cleaner by choosing options other than red, they merely prevent its further deterioration. The lake improves through natural processes, which serve to flush out the pollutants periodically. Consequently, every five rounds the water quality index is moved upward 10 units with large number of plants or five units with a small number of plants. We have also used a die roll to determine how much the water quality improves every five rounds (we increase water quality by 2 times the die roll). This decision is also an opportunity for the facilitator to “fine tune” the simulation to his or her audience. We will move it up less with less competitive groups. So as to make the participants think you aren’t controlling the outcome, however, this decision should be made up front and announced.

Payoff Matrices

The payoff matrices for determining payoffs from red and black choices are presented in the power point file. While these payoffs could be included in the participants’ materials, it is preferable that the students experience the consequences of their actions one matrix at a time and deduce the pattern underlying the payoff matrices as the simulation progresses. When Lake quality is at zero, the “0” matrix is used. When Lake Quality is at negative one, the “-1” matrix is used, and son on.

Materials and Equipment

- Projector and screen
- Dice
- Whiteboard or large paper on wall
- Copies of the players manuals
- Rewards (candy or other items)

Debrief Suggestions

Ask students to provide their scores, and their strategies (i.e. the number of reds chosen), and write these on the board. Announce the winner.

Discuss the definition of tragedy of the commons as described by Hardin in his article.

Ask what resources are currently suffering from the effects of the tragedy of the commons. Fisheries and atmosphere are at the top of the list, but there are often many local examples.

Ask what the solutions to the tragedy of the commons might be: Norms and values, Cooperation, Laws and regulations, Assignment of private property rights.

Ask what is the nature of the commons. Discuss the concept of excludability.

Discuss the concept of cooperation and how cooperation can degrade due to the pursuit of self-interest. I often use OPEC as an example of how cooperation can degrade.

Show a clip from the film, “A Beautiful Mind”, which is about Nobel Prize winning economist, Jonathan Nash. I usually show the bar scene where Jon Nash has his epiphany about the “Nash Equilibrium.” The scene is entitled “Governing Dynamics.”

The following NPR story on Elinor Ostrom is insightful, and the videos on the Prisoner’s Dilemma and Tragedy of the Commons on Kahn Academy.

http://www.npr.org/blogs/money/2012/06/12/154872185/remembering-elinor-ostrom-nobel-laureate

Students will often want to process the details of the game, rather than think about the broader meaning of the dynamics involved and their relevance to real economic systems. Such conversations are an excellent way to get them to think how they apply in real life.

PLAYERS MANUAL: COMMONS SIMULATION

You (and your team members) comprise the top management team of a sizable manufacturing facility in Kivulini – a country that is expected to experience rapid industrialization because of its low-wage structure and loose regulations. You and your team are somewhat troubled because you know that the financial performance of your plant has been discussed at headquarters and they have quite bluntly informed you that they expect higher returns on their invested capital. You are uncertain about whether the plant will be closed if your plant's profitability doesn't improve, but you are quite sure that your own compensation and career track in the company are related to the financial performance of the plant. Currently, your team has 100 pazoozas—the currency of Kivulini—in uncommitted funds.

Your plant, along with a number of other plants, is located on a large inland freshwater lake, Lacul Gunoi, upon which there are two cities (Porto Deano and Mji ya Ian) with a combined population of about 200,000 people. Importantly, all the plants (and the cities) desire a continuous, unpolluted source of water for their manufacturing processes (and quality of life as all of you live near the lake). Currently, while water quality has deteriorated noticeably in the last few years, the water is still acceptable. The lake has a restricted outlet and does replenish itself, but within limits. Unfortunately, while each plant needs a good source of water, each releases a number of toxic pollutants into the lake. Currently, neither the national nor local governments regulate either the amount of water taken from the lake or the amount of waste released into it. Consequently, the condition of the lake is determined mainly by the plants themselves.

The simulation will continue for at least 16 rounds (determined by the facilitator). You may talk freely to the other managers in your plant, but DO NOT talk to managers from other plants unless given explicit permission!!!

In sum, the problem facing you as a plant management team is, "How do we profitably operate our plant when our process is dependent on the lake as a public resource?"

PROCEDURE:

You will be confronted with a series of decision opportunities (trials) in which you must choose a course of action regarding your use of the lake water. Your management team may choose among five options prior to each trial (although only RED, BLACK, and YELLOW choices are available during the first 7 trials.):

(1) **RED:** You continue to use the lake water as you've always used it—releasing the toxic byproducts into the lake.
(2) **BLACK:** Recognizing the deterioration of water quality, you limit pollution into the lake (e.g., by storing it, treating it, cutting back on production, or subcontracting its removal). Should the opportunity present itself to discuss this problem with other plant managers, choosing black implies compliance with any agreements or understandings to reduce levels of lake pollution.
(3) **YELLOW:** You take unilateral, technical measures to make your process less dependent on lake water and, as a result, less dependent on the actions of the other plants.
(4) **BLUE:** *Available only after round 7.* You expend financial resources to enable a third party or agency to institute fines for polluters in the current trial (i.e., those choosing red).
(5) **ORANGE:** *Available only after round 7.* You use financial resources to enable an association to reward the most cooperative team up to this point in the simulation (i.e., the team which has chosen red least often throughout the simulation).

FINANCIAL OUTCOMES OF CHOICES

RED and BLACK: Financial outcomes associated with red and black choices depend on how many plants used those approaches. For example, if all plants on the lake limit their pollution (i.e., by choosing black), every plant will benefit by having cleaner water. However, if a single plant reduces pollution while all other continue to pollute (i.e., by choosing red), that single plant would incur the costs of reducing pollution with little benefit. Conversely, if all plants but one reduce their pollution by choosing black, the one rogue plant which continues to pollute by choosing red will accrue benefits from being a "free rider."

In addition to being dependent on the pattern of choices, payoffs are also dependent on the quality of the lake. Of course, as the water quality deteriorates, all plants production processes will suffer. Conversely, as water quality improves, all benefit. Red choices will cause degradation of water quality. The facilitator will announce how many peg movements downward will attend each red choice (usually one or two). Black choices, on the other hand, neither degrade nor improve water quality. Water quality is only improved by natural processes; the lake water is flushed out by the annual, and often heavy, spring runoff (every five periods)

These payoffs will be displayed for each trial and the status of the lake will be shown by the location of a marker on a board, strip, or blackboard. The marker will move up or down as the status of the lake changes. Every five trials, the peg will be moved up as a consequence of the natural restoration of the lake.

YELLOW: The yellow alternative—reduced dependence—costs a fixed amount of 20 pazoozas in the trial it is chosen. However, this choice adds 2 pazoozas onto whatever you earn or lose for the remainder of the simulation. This return takes effect three trials after the investment. The reasoning is that R&D used to develop a process which is less dependent on lake water will cost the company initially in the developmental phase, but have a future payoff after an implementation phase. Yellow may only be chosen once, however, after three implementation trials, the 2 pazooza payoff from choosing Yellow continues throughout the game. While there is some inconsistency in playing red after choosing yellow, for simplicity, this bonus is granted regardless of the option selected.

BLUE and ORANGE: The blue alternative (fines) and orange (reward) alternative each cost 3 pazoozas (i.e., the resources expended by your plant to initiate a third party, agency, or association which enforces the fines and to give rewards) in each trial it is chosen.

The effect of the blue choice (i.e., the fine) is that it takes away all pazoozas that red choosing firms would have had if the fine had not been imposed and imposes a 5 pazooza fine. However, just as in the real world not all polluters are caught. In this case polluters are caught about 33% of the time (actually a very high rate of enforcement effectiveness). A die roll will determine enforcement. Those who are caught will have their identity made public by the facilitator. To keep things simple, in the event that two or more teams choose blue, we maintain the 33% catch rate arguing that the extra resources are used up in "administrative overhead."

The orange choice rewards the cleanest plant by adding 5 pazoozas to the plant that has chosen red the least often at that point in the simulation. In addition, the first time orange is chosen the team will receive the "Green Award". The facilitator will announce the winner of the award. Ties between two or more teams will be resolved by a coin toss. The effect of these choices is summarized in the table below.

INDICATING YOUR CHOICE AND RECORD KEEPING:

Your management team will indicate your choice when the facilitator or assistant comes by your plant (a color chip is stapled in your simulation folder—you may choose to point to the color of your choice). Each plant's management team will be given a profit/loss statement for recording the payoff obtained for each trial and for keeping track of their cumulative gain (or loss). At the beginning of the simulation, the cumulative score is 100 pazoozas.

Costs & Earnings Schedule

Color	Earnings/Costs for Team	Consequences for Other Plants	Lasting Effects
Red	See Table	—	—
Black	See Table	—	—
Yellow	-20 Pz	—	+2 to Team starting 3 trials after investment
Blue	-3 Pz	"Red" Plants -5 Pz fine & loss of payoff*	—
Orange	-3 Pz	Most Exemplary Plant +5 Pz	—

* If caught (determined by die roll).

ADMINISTRATOR'S SCORE SHEET

TRIAL	PLANT # 1	2	3	4	5	6	7	8	TOTALS BK	RD	YL	BL	OR
1 (B, R, Y)													
2													
3													
4													
5 (*, ^)													
6													
7													
8 (#, ALL)													
9													
10 (*)													
11													
12 (#)													
13													
14													
15 (*, #)													
16													
17													
18													
19													
20 (*, #)													

(*) Lake Renewal – Move indicator up according to die roll

(#) Conference trial (initial conference (s) by representative)

(^) Appeal to conscience (President of Kivulini asks industry to reduce pollution)

Particpant Profit/Loss Account

Team # ___________

				Total for	Cumulative
Trial #	Choice*	Score	Adjustment	Trial	Score
0					100pz
1	________	________	________	________	________
2	________	________	________	________	________
3	________	________	________	________	________
4	________	________	________	________	________
5	________	________	________	________	________
6	________	________	________	________	________
7	________	________	________	________	________
8	________	________	________	________	________
9	________	________	________	________	________
10	________	________	________	________	________
11	________	________	________	________	________
12	________	________	________	________	________
13	________	________	________	________	________
14	________	________	________	________	________
15	________	________	________	________	________
16	________	________	________	________	________
17	________	________	________	________	________
18	________	________	________	________	________
19	________	________	________	________	________
20	________	________	________	________	________

Notes:

Only Red, Black, or Yellow may be chosen in first 7 trials

All choices available starting in trial #8

At least 16 trials will be completed

Points for choosing Yellow begin three trials after trial in which it is chosen

POWERPOINT SLIDES AND PAYOFF MATRICES

Costs & Earnings Schedule

Color	Earnings/Costs for Team	Consequences for Other Plants	Lasting Effects
Red	See Table	—	—
Black	See Table	—	—
Yellow	-20 Pz	—	+2 to Team starting 3 trials after investment
Blue	-3 Pz	"Red" Plants -5 Pz fine & loss of payoff*	—
Orange	-3 Pz	Most Exemplary Plant +5 Pz	—

* If caught (determined by die roll).

Lake quality declines by 1 or 2 points for every RED played.

Enforcement rate for BLUE is 33%: Red plants get caught on die roll of 1 or 6.

ORANGE rewards team that plays red least often. Ties determined by die roll. Orange may be played more than once by any team.

Lake renews from spring runoff every five periods- increases lake quality 2 times die roll (unless a 1 is rolled).

Top 2 teams with greater than 140 pazooza's win.

At least 16 rounds will be played.

Particpant Profit/Loss Account
Team # ___________

				Total for	Cumulative
Trial #	Choice*	Score	Adjustment	Trial	Score
0					100pz
1	________	________	________	________	________
2	________	________	________	________	________
3	________	________	________	________	________
4	________	________	________	________	________
5	________	________	________	________	________
6	________	________	________	________	________
7	________	________	________	________	________
8	________	________	________	________	________
9	________	________	________	________	________
10	________	________	________	________	________
11	________	________	________	________	________
12	________	________	________	________	________
13	________	________	________	________	________
14	________	________	________	________	________
15	________	________	________	________	________
16	________	________	________	________	________
17	________	________	________	________	________
18	________	________	________	________	________
19	________	________	________	________	________
20	________	________	________	________	________

Notes:
Only Red, Black,and Yellowmay be chosen in first 7 trials
All choices available starting in trial #8
At least 16 trials will be completed
Points for choosing Yellow begin three trials after trial in which it is chosen

Matrix “0”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	-1	1	+10
2	+1	2	+8
3	+2	3	+7
4	+3	4	+6
5	+4	5	+4
6	+5	6	+3
7	+6	7	+1
8	+7	8	-1

Matrix “-1”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	-2	1	+9
2	0	2	+7
3	+1	3	+6
4	+2	4	+4

Matrix “-2”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	-3	1	+8
2	-1	2	+6
3	0	3	+4
4	+1	4	+2
5	+2	5	-0
6	+4	6	-1
7	+5	7	-2
8	+6	8	-3

Matrix “-3”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	-4	1	+6
2	-2	2	+4
3	0	3	+2
4	+1	4	0
5	+2	5	-2
6	+4	6	-4
7	+5	7	-5
8	+6	8	-6

Matrix “-4”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	-5	1	+4
2	-3	2	+2
3	0	3	0
4	+1	4	-2
5	+2	5	-4
6	+3	6	-5
7	+4	7	-6
8	+5	8	-7

Matrix “-5”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	-6	1	+2
2	-4	2	0
3	-2	3	-2
4	0	4	-4
5	+1	5	-5
6	+2	6	-6
7	+3	7	-7
8	+4	8	-8

Matrix “-6”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	-8	1	0
2	-7	2	-2
3	-5	3	-4
4	-2	4	-5
5	-1	5	-6
6	0	6	-7
7	+1	7	-8
8	+2	8	-9

Matrix “+1”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	+0	1	+11
2	+2	2	+9
3	+3	3	+8
4	+4	4	+7
5	+5	5	+5
6	+6	6	+4
7	+7	7	+2
8	+8	8	0

Matrix “+2”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	0	1	+12
2	+1	2	+10
3	+2	3	+9
4	+3	4	+8
5	+5	5	+6
6	+7	6	+5
7	+9	7	+3
8	+10	8	+1

Matrix “+3”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	+1	1	+13
2	+2	2	+11
3	+3	3	+9
4	+4	4	+7
5	+6	5	+6
6	+8	6	+5
7	+10	7	+4
8	+11	8	+3

Matrix “+4”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	+2	1	+14
2	+3	2	+13
3	+4	3	+11
4	+5	4	+10
5	+7	5	+8
6	+9	6	+7
7	+11	7	+6
8	+12	8	+5

Matrix “+5”

Number of Black Plants in Trial	Outcome	Number of Red Plants in Trial	Outcome
1	+3	1	+15
2	+4	2	+14
3	+5	3	+12
4	+6	4	+11
5	+8	5	+9
6	+10	6	+8
7	+12	7	+7
8	+13	8	+6