



Module 4: Plant Growth, Management & Pest Control

Hands-On Activity Rubric – DIY Spore Print & Culture

Teacher Guide (Pages 1-6 & Rubric pages 7-13) for HOA Module 4

Lesson B - HOA B1

Overview & Purpose:

In this activity, students investigate a **biological plant disease (powdery mildew)** and a **natural treatment (clove oil)** as a hands-on illustration of integrated pest management (IPM). The purpose is to reinforce the concepts in Module 4 Lesson B on sustainable pest control. Lesson B focuses on pest and disease management in crops, introducing IPM strategies (e.g., cultural, biological, and chemical controls) that reduce reliance on synthetic pesticides. The DIY Spore Print & Culture activity brings these ideas to life by having students *capture a plant pathogen* and observe how an *organic fungicide* (clove oil, derived from clove plants) can inhibit it.

Key connections to Module 4 content:

- **Lesson A (Plant Growth & Health):** Students have learned what plants need to thrive and how stressors (such as pests and diseases) can affect growth. This activity links to the previous one by showing a common plant disease in action.
- **Lesson B (IPM – Pest Control Strategies):** This HOA is primarily aligned with Lesson B. It gives a concrete example of IPM tactics: **monitoring** (detecting spores as an early warning) and using a **targeted, low-toxicity treatment** (clove oil) instead of broad-spectrum synthetic chemicals. Emphasize to students that clove oil is a botanical pesticide, fitting into IPM as a natural, generally safer form of chemical control. The activity also touches on biological knowledge (the fungal life cycle) and cultural practices (removing infected material, etc.) during the debrief.
- **Lesson C (Systems & Sustainability):** Though less direct, you can circle back to Lesson C themes by highlighting **systems thinking** – how this small lab mimics a larger system of crop protection. It also connects to discussions of how organic farming or sustainable practices find alternatives to conventional chemicals. This sets the stage for students to think about real-world implementation: for instance, could a school garden use a clove oil spray for mildew? What are the trade-offs?

Overall, this activity aims to develop students' lab skills (safe handling of microorganisms, observation, data recording) while deepening their understanding of **IPM** as a holistic approach to pest management. Students will see with their own eyes that a **waste-derived or plant-derived substance can control a plant disease**, underscoring the curriculum's emphasis on turning natural products or wastes into resources (in this case, cloves, a spice, into a pesticide). This also reinforces the principle of minimizing environmental impact: clove oil is less harmful to the ecosystem than many synthetic fungicides, aligning with sustainability goals.

Teacher Setup & Preparation:

Materials & Prep Work (Before Class):

- **Agar Plates:** Prepare Petri dishes with nutrient agar suitable for fungal growth ahead of time. Potato Dextrose Agar (PDA) is ideal for culturing fungi like powdery mildew. You'll need two plates per student group. Pour plates a day in advance (to solidify) or use pre-poured plates. *Label sets of two plates for each group* as "Control" and "Clove" for easy distribution, or have students label them. Keep plates sealed until use to prevent contamination.
- **Powdery Mildew Samples:** Collect leaves with active powdery mildew infection. Ideal sources include squash, pumpkin, melon, cucumber, rose, or zinnia leaves – anything with the characteristic white powdery spots. You want fresh, **visible spores**. Collect these as close to the activity time as possible (the morning of, or day before and keep cool) so spores are viable. Have at least one decent-sized infected leaf per group. If large leaves are available, a single leaf can be shared by multiple groups (different sections can be used). *Pro tip:* If powdery mildew is scarce seasonally, you can simulate it by lightly dusting a leaf with **powdered yeast or flour** to mimic spores for the pressing step – though actual mildew is preferred for authenticity.
- **Clove Oil Solution:** 100% clove essential oil can be obtained from health stores or lab suppliers. Full-strength oil is quite potent. To facilitate even application, you may prepare a **diluted clove oil solution**: e.g., mix 1 part clove oil with 3–4 parts 70% isopropyl alcohol (or ethanol) in a dropper bottle. This dilution helps the oil spread on the agar and not just sit as a bead, because the alcohol will carry it and then evaporate. *Caution:* Clove oil and alcohol are flammable – ensure no open flames if students are using it. If you prefer not to use alcohol, you can still apply clove oil directly – just instruct students to use a very small drop and possibly spread it gently with a sterile swab.
- **Droppers/Pipettes:** Provide separate droppers for water and clove oil to each group (or have them pre-measured: e.g., small disposable pipettes with water, and the clove oil dropper bottle to share, supervising its use).
- **Gloves & Safety:** Ensure you have enough gloves for all students. Also, have paper towels and a disinfectant (like 10% bleach solution or ethanol spray) on hand for any spills or for wiping down surfaces after the activity. Although powdery mildew is not dangerous, it's good practice to disinfect surfaces post-activity. Students with mold allergies or asthma should be advised to be cautious or possibly wear a dust mask; however, since plates remain sealed, exposure should be minimal.
- **Incubation Space:** Designate a safe place in the classroom or lab to store the inoculated plates between observations. Room temperature (20–25°C / 68–77°F) works fine. They don't need light; ambient light is okay. Avoid very cold or very hot areas. You can place plates in a plastic box or tray. Remind others not to disturb them.
- **Timeline Planning:** The initial setup can be done in one class period (roughly 30 minutes for instructions and activity execution). Plan for at least one follow-up observation during the next class (if meeting daily, perhaps two days later). If possible, a second follow-up on another subsequent day will strengthen the activity (students can see progression). If class scheduling is tricky, one follow-up is

okay – just adjust expectations (maybe wait ~4–5 days and do a single observation). Powdery mildew growth might be evident by day 3 or 4; by a week it's usually very clear. You could also have students photograph the plates if extending observations over a weekend.

- **Alternative if no Growth:** In case the powdery mildew does not grow on agar (some species are obligate parasites and might not colonize well without the plant), consider a backup demonstration: for instance, have a **slide or microscope ready** with some spores, or simply use the opportunity to discuss why some fungi need a live host. However, many teachers report at least some visible growth of powdery mildew mycelium on nutrient agar for a short period, enough to compare relative growth. You might also leave a small piece of the infected leaf on one half of each plate (with and without a drop of clove oil) to see if that supports growth; though this complicates the variables, it can help the fungus continue to live off the leaf tissue a bit. Use your judgment and time – the primary goal is to see “more vs. less” fungus with vs. without treatment.

In-Class Introduction (Context for Students):

Before starting the activity, remind students that **powdery mildew** is a common fungal disease that looks like white powder on leaves. It can reduce plant growth and yield by impairing photosynthesis. Farmers often have to manage it, especially in squash, grapes, etc. Ask if anyone has seen it in gardens or at home. Then introduce **clove oil** – ask if they know cloves (maybe from cooking or the clove spice). Explain that clove oil contains **eugenol**, a compound with antifungal and antiseptic properties (it's even used in dentistry to numb gums). This sets the stage: “We'll test if clove oil can stop powdery mildew spores from growing.” This should pique curiosity.

Emphasize that this is a **mini-lab version of what farmers do**: identify a pest problem and use an appropriate solution. We're essentially *cultivating the pest* in a controlled way to see how a treatment works. Also, quickly review safety and sterile technique: no opening plates after setup, etc.

Expected Results & Observations:

During the Activity (Day 0): Students press leaves on agar. They likely won't see anything immediate except perhaps a slight leaf imprint or bits of leaf fuzz. This is fine. Once they add water or clove oil, the agar around that spot will look wet (for water) or oily (for clove). The clove oil often has a yellow tint and a strong smell. Plates are sealed – remind them to note any initial differences (smell of clove plate, etc.).

First Follow-Up (Day 2–4): By 48–72 hours, you may start seeing fine white *cottony spots* on the control plates. These are powdery mildew colonies starting to grow. The clove oil plates might still look mostly clear, or have much smaller/fewer colonies. Common observations:

- **Control plate:** one or more fuzzy white patches where the leaf was pressed. They might be small at first (a few millimeters) but clearly present. Students might also notice a bit of white “ring” outlining where the leaf contact was.
- **Clove oil plate:** often no growth at this stage, or maybe extremely tiny specks of white. Some students might think nothing is growing at all on the treated plate initially. If there is growth, it's usually at the periphery of where the oil was (perhaps the oil didn't spread there). Clove oil might leave a slight oily residue visible on the agar surface.

Encourage students to measure any visible colony. If only the control has growth, they can already qualitatively say “clove oil stopped it so far.” If contamination appears (e.g., a green or black mold spot that doesn’t look like powdery mildew), have them note it but focus them on the white mildew.

Second Follow-Up (Day 5–7): By one week, the differences should be pronounced:

- *Control:* The powdery mildew colony could be quite large – sometimes covering the majority of the plate if conditions are good. It will appear white and fuzzy, and may start producing new spores (looking powdery). There might be a distinct border matching the leaf shape, or it might have radiated outward. Some water might have evaporated, but the colony itself can create a humid microclimate under it.
- *Clove Oil:* If clove oil was effective, the treated plate will have either no mildew or only a very limited growth. Often, you’ll see perhaps a small colony or two at the very edge of the plate (where maybe the oil’s effect was weakest, or a spore bounced there during setup). The area where the oil drop was might be totally clear of growth, or have a thin filmy mycelium that never fully developed. Students might also note the smell: the clove aroma can linger in the plate, whereas the control might start to have a typical musty odor of mold.

Data trends: Students should end up with something like: “Control colony ~ X mm, Clove colony ~ Y mm” with $X \gg Y$. It’s not uncommon to see near 100% inhibition (no growth on clove plate at all), in which case $Y = 0$ and percent inhibition = 100%. In other cases, maybe control is, say, 90 mm (plate full) and clove is 10 mm, giving ~89% inhibition. Any substantial difference works for the learning outcome.

Teaching notes: If a few groups get unusual results (e.g., their control didn’t grow either – maybe they didn’t get spores on it, or something went wrong), use it as a talking point for experimental error or variability. Perhaps have one “demo” plate pair that you prepared as a reliable example to show the class, in case some groups have issues.

Also, highlight to students if they notice: *The clove oil might have prevented spore germination entirely in the area it contacted.* Sometimes you can see a stark contrast – a ring of growth on the control vs. a clean circle on the treated. This visual drives home the effect.

Guidance for Discussion:

Use these guiding questions and expected answers to debrief the activity:

- **“What differences do you observe between the control plate and the clove oil plate?”**

Students should point out that the **control plate** has significantly more fungal growth (often a big white patch), whereas the **clove oil plate** has little to no growth. This is the core observation. Encourage them to use their data: e.g., “Our control had a colony ~5 cm across covering most of the plate, but the clove plate had only a few millimeters of growth” or “no visible colonies.”

Follow-up: Ask **why** they think this difference exists. Expected student reasoning: “*Because the clove oil killed or inhibited the fungus, so it couldn’t grow like it did on the control.*” This leads into discussion of clove oil’s properties.

- **“How effective was the clove oil? What was the percent inhibition you calculated?”**

Go around and have groups share their percent inhibition. Many will have high numbers (70–100% range). If a group got, say, 100%, they observed zero growth on the treated plate – a good chance to applaud that clear result (“Complete inhibition!”). If some got lower percentages (maybe their clove oil spread unevenly, allowing some growth), have them describe what they saw – e.g., “*a small colony grew at the edge, so it wasn’t 100% stopped.*”

Emphasize interpreting the number: For example, “80% inhibition” means **the clove oil prevented 80% of the fungal growth** compared to what would have happened with no treatment. It quantifies effectiveness. This links nicely to how scientists evaluate real treatments – they often look for a high percentage of control.

- **“Why do you think clove oil inhibits the fungus? What might be happening at the microscopic or chemical level?”**

Here, students may give intuitive answers like “*Clove oil is like a poison for the mold*” or “*It kills the spores.*” That’s fine. You can expand: indeed, clove oil contains **eugenol**, which is known to damage fungal cell walls and interfere with their enzymes. You can mention that humans have long used plant extracts (like spices) to prevent spoilage and infections – clove, cinnamon, thyme, etc., have antimicrobial properties. So in essence, clove oil is acting as a **natural fungicide**. If students ask, eugenol is also why clove oil numbs pain (it’s antimicrobial and anesthetic). Keep the explanation at a level appropriate to your class; the key point is *natural products can have potent bioactive effects*.

If some students suggest that maybe the clove oil just created a physical barrier or some other idea, entertain that: “*True, it could also simply block the spores if it coated them – but given that it’s a strong chemical, the more likely reason is it chemically harmed the spores.*” If anyone had contamination issues (other molds/bacteria), you might note if clove oil seemed to inhibit those too (often it will).

- **“How does this experiment tie into what we learned about IPM and sustainable agriculture?”**

This is the big picture question. Look for answers that mention:

- Using a **natural product instead of a synthetic chemical** (this reduces chemical residues, environmental harm, and is often allowable in organic farming).

- The idea of **targeted treatment**: we only treated where the disease was (in the plate where spores were), akin to treating infected plants specifically rather than spraying everything blindly.
 - **Monitoring**: In our lab, we first captured spores to confirm the disease; in a field, a farmer scouts for disease signs before deciding to act. This prevents unnecessary pesticide use.
 - **Integration with other methods**: Maybe a student will mention you'd also remove or isolate infected leaves (cultural control) so the disease doesn't spread – tie that in as a complementary IPM step.
 - **Systems thinking**: Recognizing that what they did in a Petri dish could scale up. For example, they might imagine making a clove oil spray for a whole plant. In fact, you can share that some organic gardeners do use diluted clove or neem oil sprays to combat powdery mildew. Also mention other natural treatments like baking soda solution or milk spray – connecting to knowledge that there are multiple tools besides synthetic fungicides.
 - Possibly touch on **economics/feasibility**: Clove oil might be more expensive or slower-acting than commercial fungicides, so farmers have to weigh options. This shows why not all sustainable solutions are one-size-fits-all, but experimentation (like they did) helps identify what could work.
- Encourage students to see that **IPM is about combining knowledge and methods**: here we used knowledge of the pathogen (a fungus that produces spores) and a method derived from natural sources to tackle it. It's a great example of the kind of innovation sustainable agriculture promotes – turning to nature for solutions (in this case, using a plant's own chemical defense – clove oil – to protect another plant).
 - **“Can you think of other examples of natural or less-toxic remedies for plant pests?”**
This is more open-ended, but you might get responses like: neem oil, ladybugs for aphids (biocontrol), introducing predatory insects, using insecticidal soap, garlic or chili pepper sprays, etc. Relate their answers back to IPM categories (biological control, botanical insecticides, cultural practices like crop rotation or pruning diseased parts). This solidifies their understanding that what they did is part of a larger suite of strategies.

Closing the Discussion:

Reiterate that the **results they got support the idea that clove oil has fungicidal properties**. In real farming, one experiment isn't enough – but it aligns with existing knowledge (clove oil *is* used in some organic fungicide products). So they essentially confirmed on a small scale something that scientists and farmers have researched. This should make them feel the experiment was authentic!

Also circle back to the notion of **sustainability and systems**: We addressed a plant health issue by using a solution from nature (cloves) – thus connecting plant pathology, chemistry, and environmental science. It's an example of looking at the food system (crop protection) and finding innovative solutions that reduce waste or harm (clove oil is a byproduct of clove farming, and using it for pest control adds value and reduces need for synthetic chemicals).

Troubleshooting & Tips:

- **No Growth on Control Plate:** If a group sees no growth on the control either, it could be that not enough spores were transferred or the leaf was not heavily infected. Check if other groups got growth – if yes, use those as the example and have the group share what should have happened. If across the board there's little growth on controls by the final day, it may be the powdery mildew species didn't take to the agar. In that case, discuss the concept (the clove oil likely would have worked – possibly the fungus just couldn't grow without its plant). You could show a pre-prepared example or photos if you anticipated this. Emphasize the concept over the data if needed.
- **Excessive Contamination:** Sometimes other molds (black, green, etc.) or bacteria show up. If they do, often the clove oil plate will have *less* of those contaminants too (because clove oil is broadly antimicrobial). Use this observation to note clove oil's wide effects. Ensure students focus on the powdery mildew (white growth) for their measurements. If a plate is completely overrun by a contaminant (e.g., a fast-growing mold), you might discard that data set and have the group partner with another group to witness results. This itself is a learning moment about maintaining sterility and how experiments can get confounded.
- **Odor:** The classroom might smell quite strongly of cloves during setup and when plates are opened for disposal. It's generally pleasant, but ensure ventilation if needed. Some students might associate it with holidays (cloves in oranges, etc.), which can be a fun aside.
- **Plate Disposal:** At the end, to dispose safely, you can collect all sealed plates and autoclave them. If an autoclave isn't available, you can soak plates in a bleach solution (10%+) for a day, or instruct students to double-bag them and throw them out (per your school guidelines). Since they're sealed, the risk is low, but proper disposal is a good practice to model.

Rubric for Assessment

Use the **Data Collection Worksheet** and students' participation to assess understanding. The worksheet responses will show both their observational skills and conceptual grasp. The rubric below provides criteria for evaluating their performance. You may assign point values (for example, 4 = Exemplary, 3 = Proficient, 2 = Developing, 1 = Beginning) for each category, for a total of up to 20 points. This can be used as a formative assessment or part of a lab/activity grade.

Grading Rubric (Short Version)

Use this quick-reference table to evaluate short-response, short-essay, and design-based answers. See page 15 for the detailed rubric.

| Criteria | Exemplary (4 pts) | Proficient (3 pts) | Developing (2 pts) | Beginning (1 pt) |
|--|--|---|--|--|
| Data Collection & Accuracy (Colony diameter, treatment notes, % inhibition) | All measurements recorded accurately and on time; data log complete, neat, and easy to follow. | Most measurements recorded; log mostly complete; minor errors or missing entries. | Several data points missing or inaccurate; log somewhat unclear or disorganized. | Minimal or no data recorded; log incomplete and difficult to follow. |
| Growth & Treatment Analysis (Comparing water vs. clove oil, calculating % inhibition) | Thorough, accurate analysis with calculations complete; clearly identifies which treatment worked best with strong evidence. | Analysis mostly accurate with minor calculation or explanation errors; identifies main treatment effect. | Limited or vague analysis; incomplete or incorrect calculations; weak link between data and conclusions. | Little or no analysis; no clear use of data to support conclusions. |
| IPM Connections (Cultural, Biological, Chemical, Monitoring) | Demonstrates strong understanding of IPM; clearly explains how results connect to at least 3–4 strategies. | Shows good understanding of IPM; connects results to at least 2 strategies. | Limited or vague IPM connections; only 1 strategy identified or poorly explained. | No evident understanding of IPM strategies or how results apply. |
| Communication & Presentation (Clarity, organization, CER poster/worksheet) | Work is neat, organized, labeled with units; CER poster and IPM plan are clear, logical, and show strong effort. | Work is mostly organized; most labels/units present; CER poster and IPM plan understandable with good effort. | Work somewhat disorganized; some missing labels, unclear explanations, or low effort visible. | Work messy, incomplete, or very hard to follow; little effort shown. |

Rubric Long Version

Use the rubric below to evaluate student performance on this activity. You may assign point values (e.g., 4-3-2-1 or 0) for each category and sum them, or use it qualitatively to gauge understanding and skills. The criteria cover students' experimental execution, data analysis, conceptual understanding, and connections to broader ideas.

Criteria 1: Data Collection & Observations

- **Exemplary (4 pts):** All relevant observations and measurements are thoroughly recorded. The student's data tables/logs are complete with dates and detailed descriptions at each observation. Plate measurements are accurate and recorded with appropriate units (e.g., mm). The student clearly noted differences between treatments (e.g., described growth in both plates meticulously). It's evident they followed the procedure carefully (plates labeled, sealed, and observed without opening).
- **Proficient (3 pts):** Most observations and data are recorded, with maybe only minor details missing. The student's measurements are mostly accurate (perhaps a small rounding or unit oversight). They noted the main differences between the clove oil and control plates, though descriptions might be a bit brief. The data is organized and shows they generally adhered to the procedure.
- **Developing (2 pts):** Some observations or data are missing or unclear. The student might have skipped an observation day or failed to note a measurement. Records might be disorganized (e.g., writing observations in prose instead of the table or forgetting units). They observed the basic outcome (which plate had more/less mold) but with minimal detail or possibly some inaccuracies. There could be signs of not fully following instructions (e.g., plates not labeled in notes, unclear which plate was which in their descriptions).
- **Beginning (1 pt):** Little to no useful data recorded. Observations are very sparse or absent (e.g., "it grew" without clarification). Measurements are missing or clearly incorrect (like recording "10 cm" when the plate is only 9 cm across, indicating confusion). The student's notes might mix up which plate was the control vs. treatment, or they may have not recorded anything beyond Day 0. This level suggests a lack of engagement with the observation process.

Criteria 2: Analysis & Interpretation of Results

- **Exemplary (4 pts):** The student provides a clear and insightful analysis of the experiment's outcome. They correctly identify which treatment was most effective (clove oil) and use quantitative evidence (measurements or percent inhibition) to back up their conclusions. They interpret the percent inhibition meaningfully (e.g., explaining what 90% inhibition implies). Any anomalies or unexpected results are noted and thoughtful explanations are offered. Their conclusion shows a strong grasp of cause and effect (e.g., "because clove oil was present, the fungus couldn't grow").
- **Proficient (3 pts):** The student accurately explains which plate had less growth and acknowledges that clove oil inhibited the fungus. They reference their data in a general way (might say "much less mold" or give one measurement). The percent inhibition is calculated correctly or close, and they mention it, though the explanation of its significance might be basic. Overall, they draw the right conclusion and have a reasonable explanation for the results. Minor gaps in linking evidence to claims could be

present, but the understanding is solid.

- **Developing (2 pts):** The student's interpretation is partially correct but incomplete. They might state that clove oil helped, but not quantify it or misuse the data (e.g., mention percent inhibition but calculated it wrong). Explanations may be surface-level: "the clove oil plate had less mold because clove oil is strong" without further detail. They understand the general outcome but don't deeply analyze it or use numbers effectively to support their point.
- **Beginning (1 pt):** The student either misinterprets the results or provides no real analysis. They might incorrectly claim the control and clove plates were the same, or fail to recognize which had less growth. There's little to no use of data in their explanation. They may offer an unfounded conclusion (e.g., "I don't think clove oil did anything" despite clear evidence, or vice versa) showing misunderstanding or lack of attention to results.

Criteria 3: Scientific Reasoning (Understanding Mechanism & Concepts)

- **Exemplary (4 pts):** The student demonstrates excellent reasoning about why the results occurred. They correctly infer or state that clove oil has antifungal properties that inhibited the powdery mildew. They might mention the concept of natural chemicals killing microbes, or even name eugenol or essential oils (not required, but some might recall or research it). They clearly connect the dots: fungus didn't grow because something in clove oil stopped it (perhaps by killing spores or preventing their germination). Their reasoning is scientifically sound given the context.
- **Proficient (3 pts):** The student provides a reasonable explanation for the effect of clove oil, even if it's not highly detailed. For instance, they might say, "Clove oil is kind of like a natural pesticide, so it killed the fungus." This is essentially correct. They understand that the clove oil had a chemical effect on the mold. The answer might lack details like specific compound names or mechanisms, but it's clear they grasp the concept that the clove oil was harmful to the fungus and that's why we saw less growth.
- **Developing (2 pts):** The student's reasoning is partially there but shows some confusion or vagueness. They may say something like, "Maybe the clove oil suffocated the mold" or "the mold didn't like the oil." These statements are on the right track (acknowledging an effect) but don't clearly explain it. They might not use scientific terms or might attribute it to something inaccurate (e.g., "the clove oil blocked the sun from the fungus" – powdery mildew doesn't need sun, etc.). They have the gist that clove oil caused the difference, but can't articulate how/why in scientific terms.
- **Beginning (1 pt):** Little to no correct reasoning is provided. The student might say "I don't know" or give a very wrong explanation (e.g., "The water grew more fungus because water has nutrients for mold, and clove oil has none" – misinterpreting the situation, since nutrients are in agar, not water). They show misunderstanding of the basic science (perhaps thinking it was luck or didn't consider clove oil's role at all). Essentially, they have not connected the experiment's outcome to any mechanism or concept.

Criteria 4: Reflection & Systems Thinking (IPM & Sustainable Connections)

- **Exemplary (4 pts):** The student makes strong connections between the activity and broader sustainable agriculture concepts. In their reflection, they explicitly mention IPM or integrated pest

management, and describe how this experiment illustrates it (e.g., monitoring a problem, using a targeted organic treatment, etc.). They might mention benefits of using clove oil/natural methods such as avoiding chemical pollution, protecting beneficial insects, or not contributing to pesticide resistance – showing a holistic view. They could also bring up other IPM tactics or real-world scenarios (e.g., “Farmers could use this method in their fields as one step, in addition to pruning diseased leaves and planting mildew-resistant varieties, to manage powdery mildew sustainably.”). Their answer indicates a clear grasp of why this approach is environmentally and agriculturally significant.

- **Proficient (3 pts):** The student provides at least one or two solid connections to the bigger picture. They might say, “This shows an example of sustainable farming because we used a natural remedy instead of a chemical fungicide, which is better for the environment.” They could mention that IPM is about using less toxic methods and only when needed – and that’s what we did by identifying the fungus and then using clove oil. Their response hits the main idea that this is a safer approach to pest control, even if it’s not very elaborative. They understand the activity’s relevance beyond the classroom experiment.
- **Developing (2 pts):** The student’s reflection is present but shallow or somewhat off-target. They may generically say “It’s better for the environment” without explaining why, or “Clove oil is organic so it’s good.” They might not use the term IPM or recall specific concepts from class, but they hint at a connection (e.g., “We didn’t use chemicals, so it’s more sustainable, I guess.”). They might focus only on the lab context (“we solved the problem in the plate”) and miss how it translates to farming systems. Overall, they need prompting to deepen their answer.
- **Beginning (1 pt):** The student provides little to no reflection on the broader implications. They might say “This has nothing to do with farming” or simply not answer the question about connections. They show no understanding of how the experiment relates to sustainable practices or IPM. They might only restate what happened in the lab without any extension to real-world context. This indicates they haven’t internalized the purpose of the activity in the curriculum.

Criteria 5: Communication & Presentation

- **Exemplary (4 pts):** The student’s worksheet and responses are exceptionally clear, well-organized, and thorough. Data is neatly tabulated, and all labels (like plate names, dates, units) are present. Written answers are in complete sentences with logical flow. Few, if any, grammatical or spelling errors. Their work shows a high level of care and pride – e.g., it’s easy to read, and they perhaps even added a small graph or diagram (not required, but some ambitious students might sketch the plates). Overall, the presentation of their findings would be understandable to anyone reading it.
- **Proficient (3 pts):** The student’s work is organized and readable. The data tables are filled out, though there might be one or two minor omissions (maybe forgot a date or a unit). Their answers are coherent and mostly complete sentences, with only minor errors that don’t impede understanding. The worksheet is mostly complete and shows good effort. Someone else could follow what they did and found without much trouble.
- **Developing (2 pts):** The presentation of work is somewhat disorganized or incomplete. Perhaps some parts of the data table are blank or confusing (e.g. wrote observations in wrong columns). There might be scribbles or cross-outs that make it hard to read. Answers to questions might be one-word or very

short, lacking context, or written in a way that is a bit hard to follow. Some questions might be unanswered. The overall effort seems uneven – some sections okay, others rushed.

- **Beginning (1 pt):** The student's work is difficult to follow, very incomplete, or extremely messy. Data might not be in tables at all (maybe they wrote a couple numbers randomly). Answers are missing for several questions, or the writing is illegible. It appears minimal effort was made to record or explain anything. The lack of organization suggests they did not take the assignment seriously or had significant trouble doing so.

Note: This rubric is a guide. You can adjust point values or weight certain criteria more depending on your learning objectives. For instance, if you're focusing on the quality of scientific explanation, you might double-weight the Scientific Reasoning category. Or if lab skills are the emphasis, Data Collection might be weighted more. Communicate to students what you're looking for (perhaps even show them this rubric beforehand) so they know how to succeed.

Additional Teaching Notes:

- **Extension Ideas:** If time allows, you could have students brainstorm or even test other natural antifungals. For example, one group could try a baking soda solution or a milk solution on another set of plates and compare results. This could lead to a broader class discussion or mini-"science fair" within the class on various IPM strategies.
- **Real-World Research Connection:** Mention that scientists study plant extracts for pest control regularly. In fact, clove oil and many other essential oils are being researched as eco-friendly pesticides. This lab is essentially replicating a piece of that research at a small scale. For instance, eugenol (from clove) and thymol (from thyme) are registered as minimum-risk pesticides by the EPA. Connecting to such facts can inspire students who are interested in science careers or show them how what they did ties to real innovations in agriculture.
- **UN Sustainable Development Goals (SDGs):** If your curriculum touches on global goals, you can tie this activity to SDG 2 (Zero Hunger – through sustainable agriculture) and SDG 12 (Responsible Consumption & Production – reducing reliance on harmful chemicals). It's an example of developing practices that keep food production safe and eco-friendly.

By the end of this activity and discussion, students should clearly grasp that **IPM is about smart, informed action** – you identify the problem (the specific pest or disease) and then choose a targeted solution that has minimal downsides. They have seen an example: identifying powdery mildew spores and using a clove oil treatment. This not only solidifies their understanding of the module content but also empowers them with a tangible demonstration that *solutions to agricultural problems can come from understanding biology and using creativity, not just industrial chemicals*. The hope is that experiences like this plant seeds (no pun intended) for future thinking about sustainability and innovation in food systems.