Biotechnology Design

2412-2

Cary, NC 2022

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Definition and Explanation of the Problem

According to the Environmental Protection Agency (EPA), 68% of Americans obtain their drinking water from water systems in their community that relies on rivers, lakes, or other bodies of surface water for their supply. However, contaminants, such as cyanobacteria, make protecting these sources a ubiquitous struggle. Scientists found in a survey of 1,161 lakes in the United States that cyanobacteria were the dominating algae in 76% of the studied locations.

Cyanobacteria is a prokaryotic, photosynthetic organism found naturally in all types of water. However, in warm and nutrient-rich water (i.e containing large amounts of nitrogen and phosphorus), it multiplies quickly and consequently forms harmful cyanobacterial blooms or cyanoHABS.

Causes (figure 1) of cyanobacteria and cyanoHABS include light availability, water temperature, alteration of water flow, pH changes, trace metals, and nutrient (nitrogen and phosphorus) loading. However, the scientific community agrees that the recent rapid growth of cyanoHABS is caused by increasing anthropogenic activities including wastewater treatment, stormwater runoff, and most notably agricultural runoff especially from agricultural practices and nitrate and phosphate fertilizers. Such activities can promote eutrophication (figure 2), a process in which concentrations of nitrogen, phosphorus, and other plant nutrients accumulate substantially. In the United States alone, eutrophication-induced damage is approximately $2.2 billion yearly.

Eutrophication consequently leads to excessive cyanobacterial growth followed by the formation of cyanobacterial blooms. Blooms block sunlight from penetrating the water, preventing the native aquatic plants' ability to perform photosynthesis and thrive. The lack of producers can reduce populations of subsequent consumers, resulting in food web collapses. Additionally, cyanobacteria usurp carbon dioxide needed by native plants for photosynthesis, eventually leading to food web collapses another way. When the cyanobacterial blooms die, aquatic decomposers deplete substantial amounts of oxygen to decompose them. Therefore, anoxic and hypoxic "dead zones" are created in which animals don't have sufficient oxygen and die off. The cycle is repeated as when animals die, more oxygen is depleted by decomposers, which further kills more organisms. As a result, the murky water and the organism kill leads to subsequent economic losses: losses due to beach clean-up activities, property losses and losses in property value, losses in tourism revenues, and losses in fishing industries. For example, an economic study of a 2014 bloom in Toledo, Ohio cited by the National Marine Fisheries Service (NMFS) estimated that the bloom caused a $10.05 million loss in shoreline property value services such as drinking water, wildlife habitat, and recreation. Additionally, according to the NMFS, researchers estimate that summer-long blooms in Lake Erie would cause $2.25-$5.58 million in fishing expenditure losses. Economic losses can also be seen in monitoring and treatment of blooms: a 2008 study by researcher D.A Steffensen found that bloom monitoring in Australia is estimated to cost over $8 million annually.

Declined water quality also results in a lack of access to clean water for many. In the 2014 Toledo, Ohio bloom, 500,000 residents were warned to not drink or bathe in the city's tap water. Exposure to such toxic water means that societal health is further at risk. Toxins produced by cyanobacteria, known as cyanotoxins, pose a serious threat to public health via ingestion from drinking water and exposed food, or exposure to toxin-filled recreational water. At least 80 species of cyanobacteria are known to produce illness-causing and fatal toxins in humans and animals like neurotoxins, which cause nervous system damage, and hepatotoxins, which cause liver damage. Such toxins (refer to figure 3) cause life-threatening issues: cancer, cytotoxicity, skin toxicity, respiratory effects (like pneumonia), gastrointestinal disturbances, kidney damage, etc. According to a Quebec public health report on cyanobacteria, the public health department received 34 reports of diseases potentially linked to toxic algae between 2006-2012. Economic losses from declined public health stem from healthcare costs as a result of higher hospital and doctor visits.

To control or eradicate cyanobacteria, and control the environmental, societal, and economic effects of it, we must address the issue contributing to the nutrients in bodies of water that promote the most growth of cyanobacteria at its core: managing agricultural runoff.

Solutions

It is important to note that no one solution can combat cyanoHABS entirely as there are multiple points and non-point sources of nitrogen and phosphorus that enter bodies of water. Additionally, the stage in which cyanobacteria is at in its growth may vary with different bodies of water. Many proposed solutions may be effective if integrated. However, that can be costly and the cost of treatment and monitoring of blooms is already very high. So, if we can identify and reduce the amount of a major pollutant that largely contributes to the ubiquitous and rapid growth of cyanobacterial blooms, then the cyanobacterial blooms in bodies of water will also cease to grow. In other words, controlling the root cause of the problem can prevent cyanobacterial promoting pollutants from entering a body of water in the first place, preventing nitrogen and phosphorus from entering the body of water in the first place, lowering cyanobacterial growth, and mitigating the further effects and costs of it. A major nitrogen and phosphorus contributor is agricultural runoff, so we can manage agricultural runoff from reaching nearby bodies of water. We propose that the most effective solution to do this is **fertilization management.**

Nitrogen and phosphate fertilizers account for a substantial amount of runoff from agricultural practices. Due to recent population growth, chemical fertilizers and pesticides are indispensable to meet food demands; nitrogen and phosphorus fertilizers, in particular, are typically used. According to data from the Food and Agriculture Organization of the United Nations, the average global use of nitrogen fertilizer and phosphorus fertilizer per cropland area as of 2015 reached 68.6 kg/ha and 30.1 kg/ha respectively. Once the fertilizers are applied to farmland, the excess nitrogen, and phosphorus runoff into surface water via irrigation events and/or rainfall. This nutrient migration process also adds to the overall complexity of the runoff system, i.e from the point of fertilizer application to before reaching a body of water (refer to figure 4). Therefore, we can manage major contributors of agricultural runoff directly so that the overall runoff formed in the first place is reduced. Therefore, less runoff overall will enter nearby bodies of water, reducing the promotion and thereby effects of eutrophication. **Fertilization management** is concerned with this very concept, as fertilizers are one of the most significant sources of nitrogen and phosphorus runoff in the modern-day. It is the most effective control method containing nitrogen and phosphorus that are commonly used in the agriculture industry. Fertilization management can be implemented with various methods.

One such method is placement, a tactical method in which fertilizer is applied to a fixed area of the soil where the plant may readily take up for use. Placement can further be done in varying ways. In fertilizer deep placement (FDP) or urea deep placement (UDP), a nutrient-dense briquette (i.e the fertilizer) is placed under the soil surface by hand or with an applicator (refer to figure 5). It is usually placed in the reduction zone of the soil. Placement in this zone ensures better distribution of the fertilizer in the plant, as the fertilizer can be pulled up by the roots and pumped into all the aerial parts of the plant. This will reduce runoff as more of the fertilizer is used instead of wasted. It was found that using this method reduced nitrogen loss by 50% in the rice field in the Taihu Lake region. Furthermore, better nutrient absorption and less nutrient runoff equate to better crop productivity and yield. The Feed the Future Initiative cites that FDP, on average, boosts rice yields by around 15-20% in comparison to alternative fertilization application methods like surface broadcasting, the method in which fertilizer is applied on the surface of a field, resulting in more nutrient runoff.

Other localized placement methods include fertilizer application in a band or hole. In fertilizer band placement or banding, nutrients are placed at least 2 inches above, below, on one side, or both sides of a seed or near developing roots so nutrients can be reached. It is best used for closely-sown row crops such as lettuce and spinach. Band placement (refer to figure 6) can reduce nitrogen and phosphorus loss by approximately 64% and 43%, respectively, because it reduces soil microbial contact and thus slows down nitrification. In fertilizer hole placement (refer to figure 7), the fertilizer is placed in a hole near a seed, plant, or group of plants or seeds at about a 7.5-10 cm distance. This method is best used for "hill" planted crops in larger areas. Hole placement reduces nitrogen and phosphorus loss by approximately 77% and 54% respectively. Localized placement is also a method of applying fertilizer in a half-circle. This method is best used for transplants such as tomatoes, cabbage, and eggplant.

Another type of fertilization management is the controlled-release of fertilizer, which allows for a slow release of nitrogen and phosphorus to adjust to the rate of crop growth while increasing nutrient use efficiency. Runoff is consequently reduced because more fertilizer is utilized rather than wasted, also yielding more crop growth (refer to figure 8) Controlled-release fertilizer was shown to lower nitrogen and phosphorus loss by 60% and 63% respectively in rice systems and 27.8% and 34% in corn systems. Optimizing fertilizer timing and application rate is also important for controlling nutrient loss because losses display seasonal characteristics, with increased nutrient loading in summer and fall and reduced nutrient loading in spring and winter.

The fertilization management techniques we have described may or may not be effective for plant growth and crop yield depending on the topography in which the farmland is on, climate and weather, seasonal changes, etc; therefore we cannot say which technique described is by far the most effective overall. However, each of these techniques has been thoroughly proven to be effective in reducing nutrient runoff in their own suited conditions. The versatility of the techniques we have described allows for farmers and agriculture businesses to utilize which technique works best for their crop yield, whilst being reassured that their choice of fertilization management will reduce runoff: reducing cyanobacterial blooms and eutrophication in surface waters near them. Furthermore, by taking this preliminary step in the migration process of runoff from the point of fertilizer application to just before entering surface water, we can eliminate further costs included in removing nutrients from the water and in treating blooms once they occur.

Another agricultural runoff controlling method is the **ecological ditch system**, which is an engineered system designed to remove agricultural runoff nutrients via plant uptake, sedimentation, sorption, transformation, and microbial metabolic activities. Ditches are an ideal place to collect and control nitrogen and phosphorus because agricultural runoff goes through a certain amount of migration time before being released into nearby water (refer to figure 4). Ecological ditches are based on traditional agricultural ditches and by creating a unique sediment-aquatic plant-microorganism system, they aid in introducing substrates, aquatic plants, and interception facilities. Periphyton is a vital component of ecological ditches and is widely distributed in natural bodies of water. It is a freshwater material that grows on submerged surfaces (ex. plants, sediments, and other objects in water) in which microalgae dominates the surface, forming long sheets or filaments that cover them. Furthermore, it can sustain a complex community consisting of bacteria, fungi, algae, and various other invertebrates. It can help rid of water pollutants via adsorption, absorption, and complexation processes. Advantages of periphyton include having large biomass, sensitivity to water quality, the effectiveness of nitrogen and phosphorus removal, etc. The selection of highly efficient ditch plants is also integral to ecological ditch systems. Researchers M. Pierobon et al. conducted experiments to remove nitrogen in vegetated and unvegetated ditches in the Po River Basin in Italy. The results showed that an average of 1.52 kilograms and 0.24 kilograms of nitrogen were removed in the vegetated ditches and unvegetated ditches respectively, indicating that aquatic plants played an essential role in the sediment-aquatic plant-microorganism system. As another example, researchers Li S et al. deduced that plant diversity has a significant influence on the capacity of ecological ditches to remove pollutants. They conducted their study on nitrogen removal in an ecological ditch vegetated with *Lythrum salicaria* and *Iris pseudacorus* in Tianjin, China, the results showed that the removal capacity of nitrogen was 1.73 kilograms per day. Plants can store enormous amounts of nutrients for self-growth during the growing seasons. However, once senescence starts, their ability to accumulate decreases. Furthermore, plant decomposition will cause the retained nutrients to be released, making it a new source of nutrients. This issue is resolved with harvest management; plant harvesting completely removes all nutrients from ecological ditches, and timely harvesting of aquatic plants in ecological ditches can promote nutrient removal and plant regeneration.

Despite the advantages of ecological ditches, the major drawback of this system is the management of ecological ditches. Large-scale harvesting necessitates a significant amount of labor, raising the cost of maintenance. Costs of managing ecological ditches are also too high to manage for small-scale agriculture operators. Furthermore, land requirements for ditches may not be in the best interest of crop growers. A smaller land area for ditches can be used, but this would equate to a smaller yield; larger ditches are much more costly to make and maintain. Therefore, the ubiquitous use of ecological ditches may not be feasible.

Tillage methods, like **conservation and rotation tillage methods**, are other alternative methods to reduce agricultural runoff. The first type is **conservation tillage** methods that help protect the soil from erosion and are effective for reducing dissolved nitrogen in the runoff. They strengthen the structure of the soil and increase the amount of organic matter in it. Two of these methods are reduced tillage and no-tillage. Researchers John C. Clausen et al. evaluated the effects of reduced tillage on farmland runoff in Vermont and discovered that it lowered runoff by 64%. In a study of no-tillage techniques, researchers Liang et al. found that runoff volume from rice-planting basins was lowered by 25.9%. However, conservation tillage methods were discovered to cause soil compaction in the long run, resulting in phosphorus accumulation on soil surfaces. In a study in the Canadian Prairies, researchers Tiessan et al. discovered that these methods lowered nitrogen concentration by 41% while increasing total phosphorus content by 42%. The second type of tillage method is **rotation tillage**, which was converted from conservation tillage by researchers Liu et. al and was found to be a better option to decrease the amount of phosphorus contained in different types of phosphorus runoff: for example, released from crop residue or contained in surface soil. They concluded that the total dissolved phosphorus decreased by 46% and the total phosphorus decreased by 38%. Rotation tillage would reduce soil compaction, which would result in less phosphorus accumulation in the soil. It lowers phosphorus released from crop residues by shortening the contact time between crop residues and surface runoff. However, rotation tillage can only be used depending on climate, soil conditions, with certain crops, and prevailing eutrophication nutrients. If these limitations aren't met in a given area, conservation tillage may be the better choice. Rotation tillage isn't a universal and versatile solution that can be used ubiquitously and therefore may not be viable.

Scenario of Possible Real-Life Applications

To demonstrate the effectiveness of fertilization management, let us consider the following scenario of a real-life scenario application of this solution.

Farmers and agricultural businesses commonly use fertilizers for a variety of reasons, including to increase fertility and promote plant growth. Farmers in the United States now use nitrogen fertilizer at a rate that is over 40 times higher than it was three-quarters of a century ago. As a result, many water bodies around farms suffer from cyanobacterial blooms. One such privately owned farm is near a large lake that provides the farm´s crops with an abundant source of water. The farm grows rice, lettuce, spinach, cucumbers, and gourds. The farm releases about 650 lbs of nitrogen and phosphorus runoff into the lake monthly; 300 lbs in nutrient runoff (approx. 150 lbs of each nutrient) from their spinach and lettuce fields, 200 lbs in nutrient runoff (approx. 100 lbs of each nutrient) from their cucumber and gourd fields, and 150 lbs in nutrient runoff (approx. 75 lbs of each nutrient) from their rice field. As a result, harmful cyanobacterial blooms formed in the lake, restricting water use for the crops and lowering crop yields.

To control the cyanoHABS, the owners of the farm referred to local pollution control inspectors, to which they advised the use of fertilization management as a potential solution to the problem. They suggested the following methods: fertilizer hole placement, and controlled-release of fertilizer.

Fertilizer band placement is best used for closely-sown row crops, so the farm owners can implement this method for their spinach and lettuce as they are grown this way. Band placement will lead to a better distribution of fertilizer in the plant. By hand or with an applicator, the farmers can deposit the fertilizer beneath the soil surface. This will reduce runoff as more of the fertilizer is used instead of wasted, reducing nitrogen runoff by around 64% and phosphorus by around 43%. While the farm has been releasing 150 lbs of each nutrient per month, after using this technique, it will only release about 54 lbs of nitrogen runoff and 85.5 lbs of phosphorus. This lowers the total runoff from the spinach and lettuce fields by approximately 53.5%, from 300 lbs to 139.5 lbs.

Fertilizer hole placement is best used in sizable areas filled with hill cultivated crops, so the farmers can implement this method for their cucumbers and gourds, in the hilly areas of their farm. They can apply the fertilizer in a hole near the seeds, the plants, or a group of plants. This method has shown a 77% decrease in nitrogen runoff and a 54% decrease in phosphorus runoff. In this stimulation with the farm, the hole placement method would reduce nitrogen and phosphorus from 100 lbs of runoff each to 33 lbs and 46 lbs respectively. Total runoff from the cucumber and gourd fields is lowered by approximately 60.5%, from 200 lbs to 79 lbs.

The owners of the farm could also use the controlled-release method on either just their rice fields or for all of their fields if that is what they prefer. The farmer would use the controlled-release method for both nutrients to supply fertilizer slowly and preferably at the pace that their plants use it. As a result, the quantity of both wasted fertilizer and runoff is limited. Nitrogen and phosphorus runoff in rice systems was lowered by 60% and 63%. So, we can expect nitrogen and phosphorus to reduce from 75 lbs of each nutrient to 30 lbs and 27.75 lbs respectively, a 61.5% reduction in total runoff in the rice fields: from 150 lbs to 57.75 lbs.

If these methods are implemented such that the farmers utilize band placement for their closely-sown crops, hole placement for their hill cultivated crops, and controlled release of fertilizer for their rice field, the total runoff from all of their fields can be lowered from 650 lbs to 276.25 lbs; a 57.5% reduction. If this can happen, cyanobacterial levels would largely decrease because we are lowering the nutrient runoff into the lake thereby reducing eutrophication.

Supplementary Information

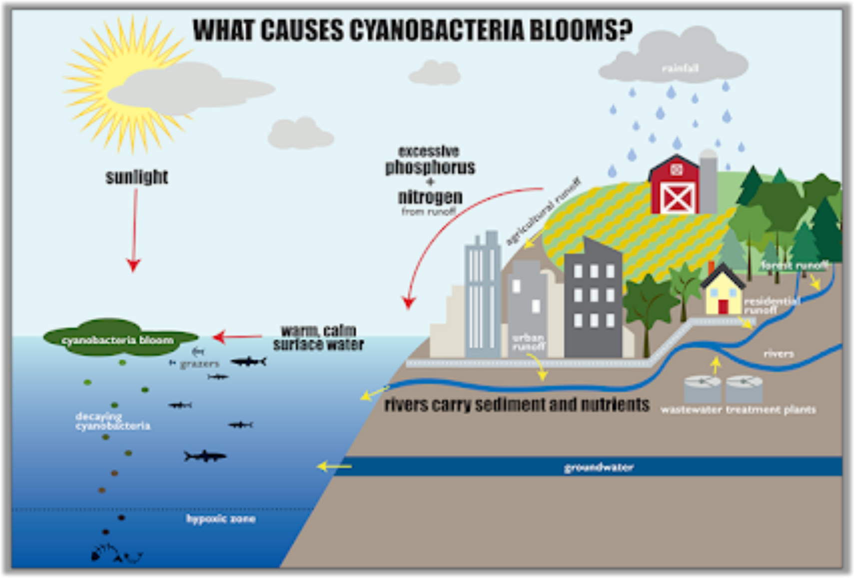


Figure 1. Natural and anthropogenic causes of cyanobacteria

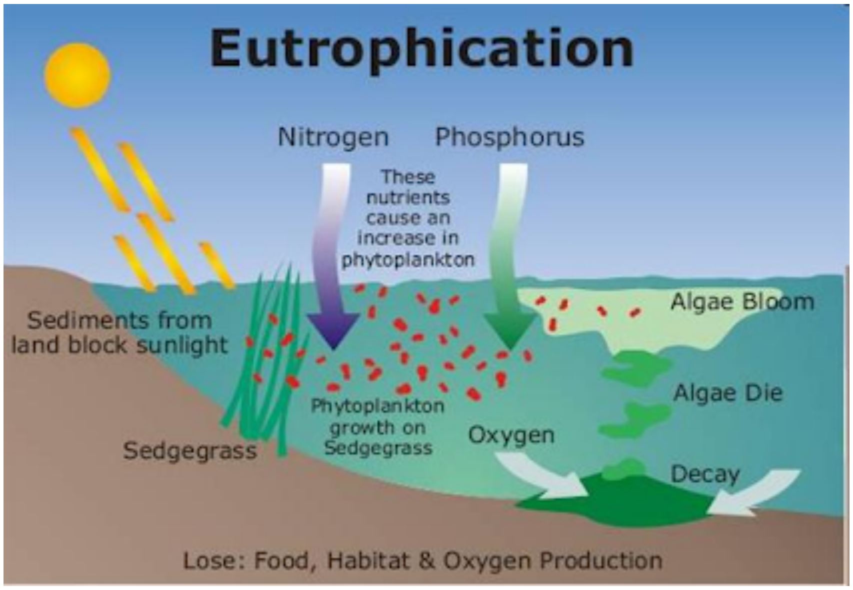


Figure 2. Process of eutrophication and the effect on marine environments

Cyanotoxins	Acute Health Effects in Humans	Most Common Cyanobacteria Producing Toxin
Microcystin-LR	Abdominal pain, headache, sore throat, vomiting and nausea, dry cough, diarrhea, blistering around the mouth, and pneumonia	*Microcystis*, *Dolichospermum (previously Anabaena)*, *Nodularia*, *Planktothrix*, *Fischerella*, *Nostoc*, *Oscillatoria*, and *Gloeotrichia*
Cylindrospermopsin	Fever, headache, vomiting, bloody diarrhea	*Raphidiopsis (previously Cylindrospermopsis) raciborskii*, *Aphanizomenon flos-aquae*, *Aphanizomenon gracile*, *Aphanizomenon ovalisporum*, *Umezakia natans*, *Dolichospermum bergii*, *Dolichospermum lapponica*, *Dolichospermum planctonica*, *Lyngbya wollei*, *Rhaphidiopsis curvata*, and *Rhaphidiopsis mediterranea*
Anatoxin-a group	Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death (experimental animals)	*Chrysosporum (Aphanizomenon) ovalisporum*, *Cuspidothrix*, *Raphidiopsis*, *Cylindrospermum*, *Dolichospermum*, *Microcystis*, *Oscillatoria*, *Planktothrix*, *Phormidium*, *Dolichospermum flos-aquae*, *A. lemmermannii Raphidiopsis mediterranea* (strain of *Raphidiopsis raciborskii*), *Tychonema* and *Woronichinia*

Figure 3. Common cyanotoxins chart and their numerous effects

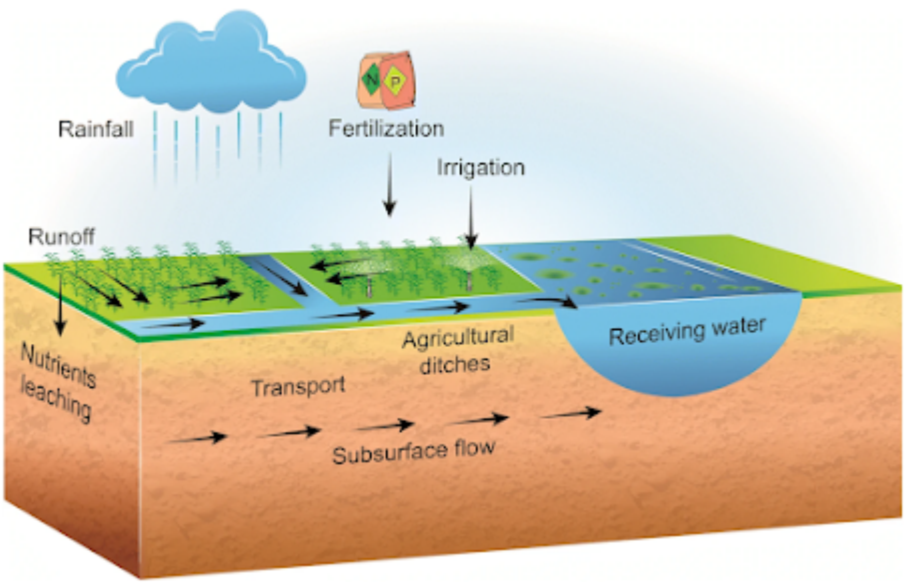


Figure 4. Fertilizers have a certain amount of transport time before they enter the water, making nutrient management during this stage possible

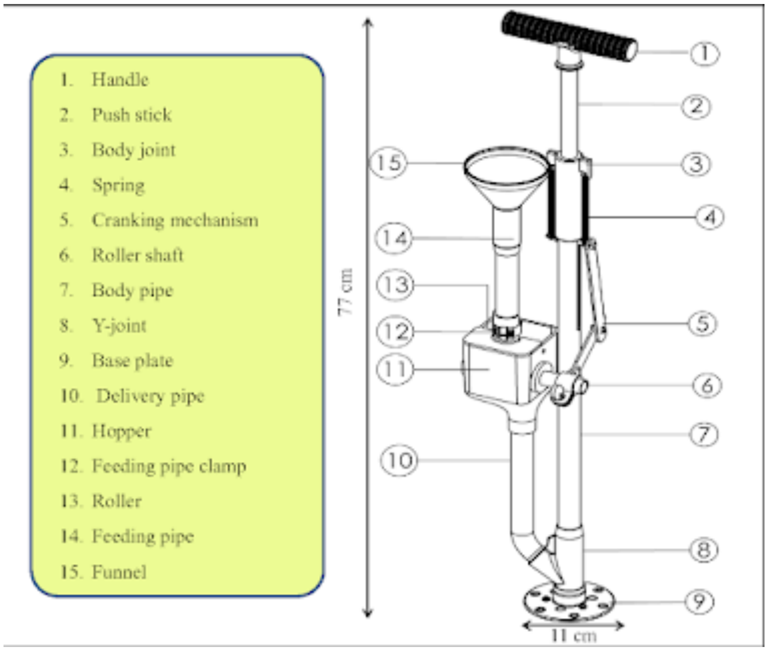


Figure 5. Example of a deep placement fertilizer applicator. Used as a pump to apply fertilizer into the soil.

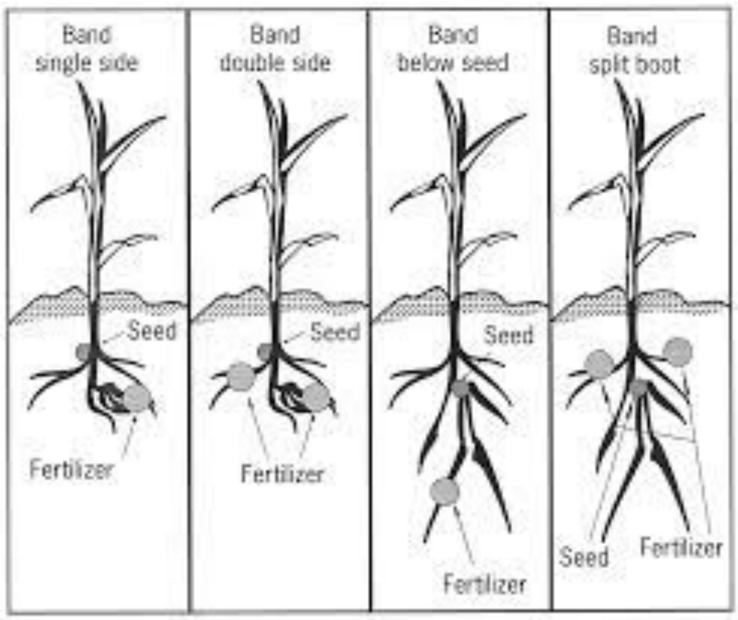


Figure 6. Example of fertilizer band placement in which fertilizer is applied directly to the roots in bands.

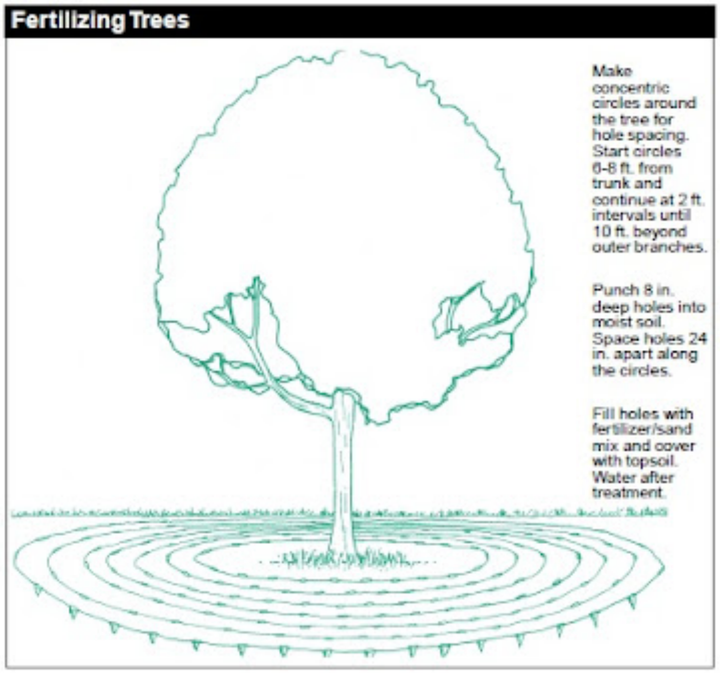


Figure 7. Example of fertilizer hole placement. Holes are made around the tree in which fertilizer can be applied.

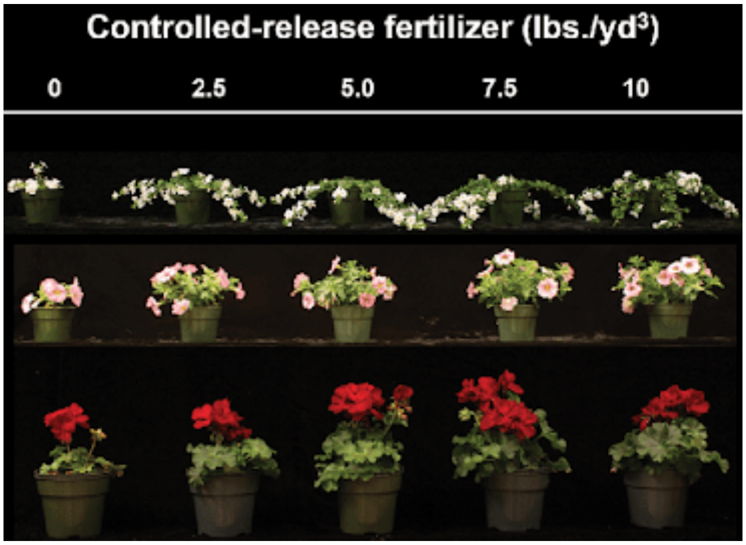
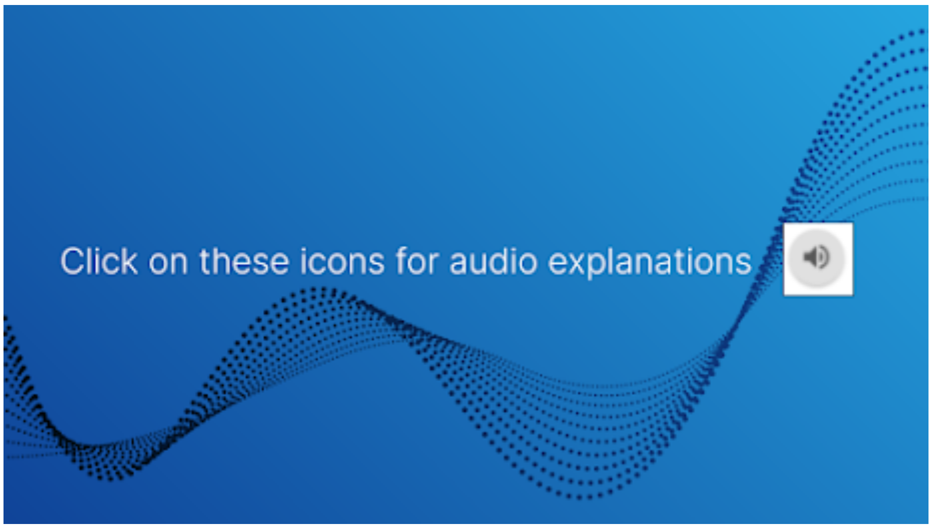


Figure 8. Controlled-release of fertilizer increases nutrient efficiency and reduces excess runoff, promoting plant growth as seen in the image with increased controlled release amounts.


Cyanobacteria Containment
T&S Environmental Services


Click on these icons for audio explanations


68%
Of Americans rely on lakes, rivers, and other bodies of water for drinking water
But an estimated
76% of 1,161 lakes
Surveyed had cyanobacteria as the dominating algae
Contaminants like cyanobacteria make protecting water sources a struggle.
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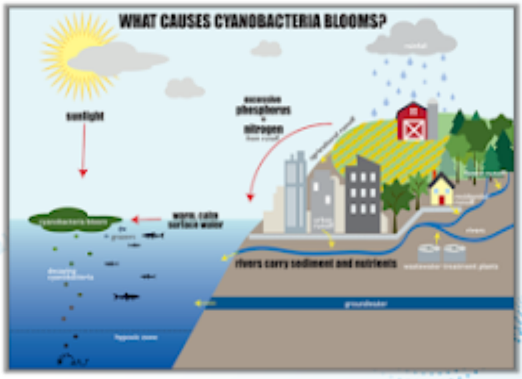
Cyanobacteria

- Prokaryotic
- Photosynthetic
- In all types of water

The Problem

- Multiplies in warm and **nutrient**-rich water
  - I.e abundant in nitrogen and phosphorus
- Rapid multiplying ➡ **harmful cyanobacterial blooms** or **cyanoHABS**

Causes



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Anthropogenic Causes
Known to cause recent rapid growth of cyanoHABS
These activities can cause **eutrophication**
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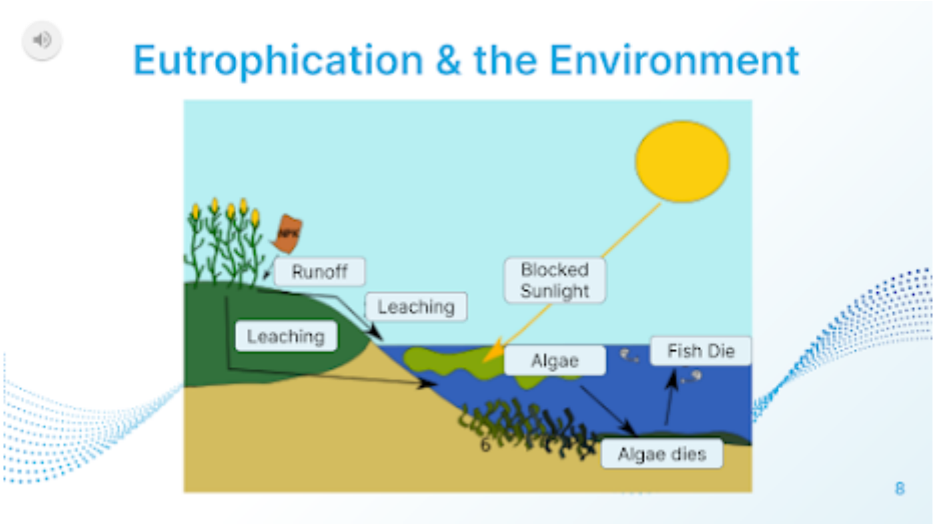
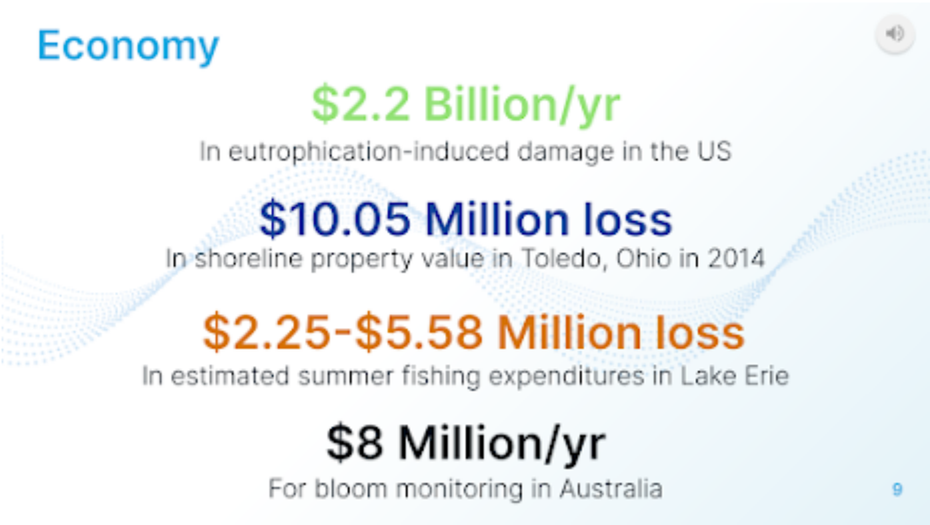

Eutrophication & the Environment
Runoff
Leaching
Leaching
Blocked Sunlight
Algae
Fish Die
Algae dies
8


Economy
$2.2 Billion/yr
In eutrophication-induced damage in the US
$10.05 Million loss
In shoreline property value in Toledo, Ohio in 2014
$2.25-$5.58 Million loss
In estimated summer fishing expenditures in Lake Erie
$8 Million/yr
For bloom monitoring in Australia
9

Societal Effects

Declining Water Quality

=

Societal Health Jeopardized

34 Reports of diseases, potentially linked to algae, between 2006-2012

At least 80 known illness-causing and fatal cyanotoxins

Increased healthcare costs

2014 Toledo Bloom

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Societal Effects Cont.

Examples

- Cancer
- Cytotoxicity
- Skin toxicity
- Respiratory effects
- Gastrointestinal disturbances
- Kidney damage

Cyanotoxins	Acute Health Effects in Humans	Most Common Cyanobacteria Producing Toxin
Microcystin-LR	Abdominal pain, headache, sore throat, vomiting and nausea, dry cough, diarrhea, blistering around the mouth, and pneumonia	*Microcystis, Dolichospermum* (previously *Anabaena*), *Nodularia, Planktothrix, Fischerella, Nostoc, Oscillatoria,* and *Gloeotrichia*
Cylindrospermopsin	Fever, headache, vomiting, bloody diarrhea	*Raphidiopsis* (previously *Cylindrospermopsis*) *raciborskii, Aphanizomenon flos-aquae, Aphanizomenon gracile, Aphanizomenon ovalisporum, Umezakia natans, Dolichospermum bergii, Dolichospermum lapponica, Dolichospermum planctonica, Lyngbya wollei, Rhaphidiopsis curvata,* and *Rhaphidiopsis mediterranea*
Anatoxin-a group	Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death (experimental animals)	*Chrysosporum (Aphanizomenon) ovalisporum, Cuspidothrix, Raphidiopsis, Cylindrospermum, Dolichospermum, Microcystis, Oscillatoria, Planktothrix, Phormidium, Dolichospermum flos-aquae, A. lemmermannii Raphidiopsis mediterranea* (strain of *Raphidiopsis raciborskii*), *Tychonema* and *Woronichinia*

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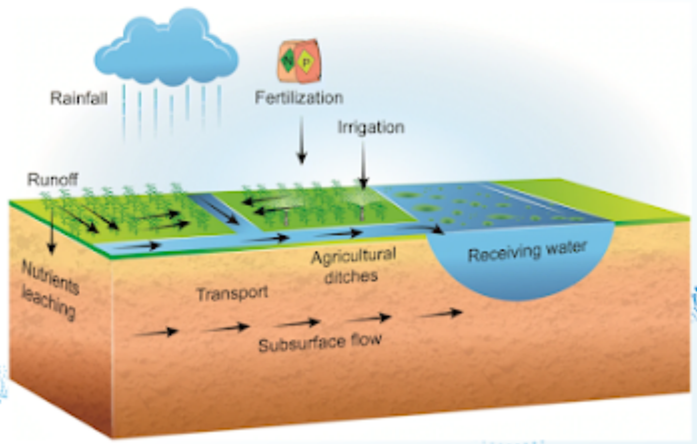
Solution:

Fertilization Management



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Techniques

SCAN ME

Deep Placement — DP	BP — Band Placement
Hole Placement — HP	CR — Controlled-Release

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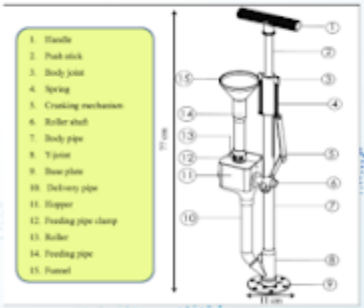
Fertilizer Deep Placement

Also Known As: Urea Deep Placement

Nutrient dense briquette placed under the soil surface by hand or applicator.

- 50% Nitrogen loss in rice fields in Taihu Lake Region
- Boosts rice yields by 15-20%



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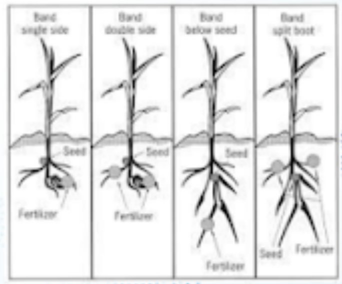
Fertilizer Band Placement

Nutrients placed within 2 inches of developing roots of plants.

- Closely-sown crops
- Nitrogen loss ≈ 64%
- Phosphorus loss ≈ 43%



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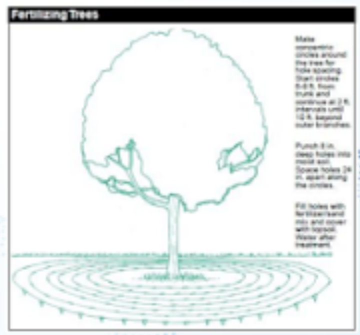
Fertilizer Hole Placement

Fertilizer placed in a hole near a seed, plant, or group of plants.

- Hill cultivated crops
- Nitrogen loss ≈ 77%
- Phosphorus loss ≈ 54%



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Controlled-Release of Fertilizer

Slowly releases fertilizer that adjusts to the rate of crop growth.

Rice Systems:

- Nitrogen loss ≈ 60%
- Phosphorus loss ≈ 63%

Corn Systems:

- Nitrogen loss ≈ 27.8%
- Phosphorus loss ≈ 34%

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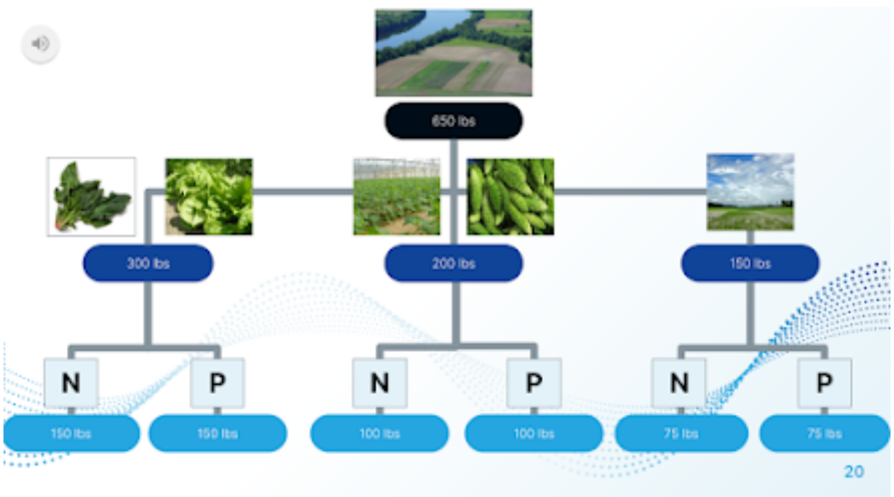
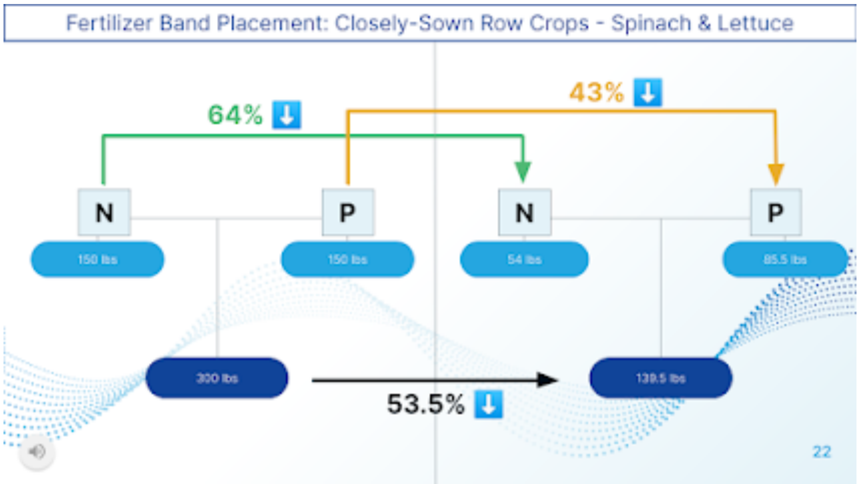
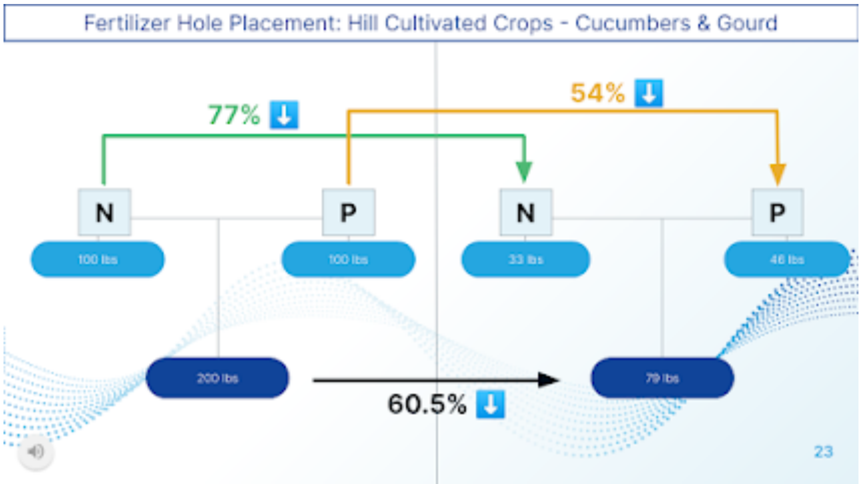
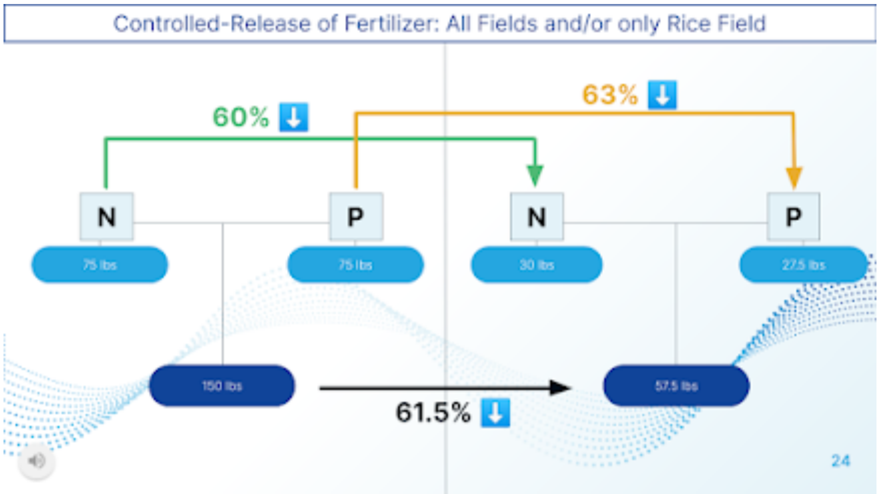
Example:
Real-Life Application


650 lbs
300 lbs
200 lbs
150 lbs
N
P
N
P
N
P
150 lbs
150 lbs
100 lbs
100 lbs
75 lbs
75 lbs
20


Local Pollution Control Inspectors' Advice
Band Placement
Hole Placement
Controlled-Release


Fertilizer Band Placement: Closely-Sown Row Crops - Spinach & Lettuce
64%
43%
N
P
N
P
150 lbs
150 lbs
54 lbs
85.5 lbs
300 lbs
139.5 lbs
53.5%
22


Fertilizer Hole Placement: Hill Cultivated Crops - Cucumbers & Gourd
77%
54%
N
P
N
P
100 lbs
100 lbs
33 lbs
46 lbs
200 lbs
79 lbs
60.5%
23


Controlled-Release of Fertilizer: All Fields and/or only Rice Field
60%
63%
N
P
N
P
75 lbs
75 lbs
30 lbs
27.5 lbs
150 lbs
57.5 lbs
61.5%
24


If all of these methods are used:
650 lbs → 276.5 lbs
57.5% ⬇️
25


Alternative Solutions


Tillage Methods
27


Ecological Ditch System
Rainfall
Fertilization
Irrigation
Runoff
Nutrients leaching
Transport
Agricultural ditches
Receiving water
Subsurface flow
28


THANK YOU

Plan of Work Log

TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK

Date	Task	Time involved	Team member responsible (student initials)	Comments
1. 11/29/2021	Research Questions	1 hour	SAC, DR, TB	what is cyanobacteria? What does it do and why is it a problem? what causes it?
2. 12/10/2021	Discussed plan of action for portfolio	1 hour	SAC, DR, TB	Made portfolio template, started filling out pages
3. 12/18/2021	Definition + Explanation	1 hour	SAC, TB	worked on the definition + explanation page
4. 01/06/2022	Solutions pages	2.5 hours	SAC, TB	Researched solutions + created pages
5. 01/18/2022	Real life applications + finalize details on portfolio	3 hours	SAC, DR, TB	Real life applications page, revised + edited portfolio, cited sources, inserted figures
6. 01/30/2022	Slideshow + find figures	3 hours	SAC, DR, TB	Made plan for slideshow, created slideshow, inserted figures into portfolio + slides

Advisor signature

Copyright Checklist

STUDENT COPYRIGHT CHECKLIST

(for students to complete and advisors to verify)

1) Does your solution to the competitive event integrate any music? ☐ YES ✓ NO

If NO, go to question 2.

If YES, is the music copyrighted? ☐ YES ◯ NO

If YES, move to question 1A. If NO, move to question 1B.

1A) Have you asked for author permission to use the music in your solution and included that permission (letter/form) in your documentation? If YES, move to question 2. If NO, ask for permission (OR use royalty free/your own original music) and if permission is granted, include the permission in your documentation.

1B) Is the music royalty free, or did you create the music yourself? If YES, cite the royalty free music OR your original music properly in your documentation.

CHAPTER ADVISOR: Sign below if your student has integrated any music into his/her competitive event solution.

I, William Holler (chapter advisor), have checked my student's solution and confirm that the use of music is done so with proper permission and is cited correctly in the student's documentation.

2) Does your solution to the competitive event integrate any graphics? ☑ YES ◯ NO

If NO, go to question 3.

If YES, is the graphic copyrighted, registered and/or trademarked? ☐ YES ✓ NO

If YES, move to question 2A. If NO, move to question 2B.

2A) Have you asked for author permission to use the graphic in your solution and included that permission (letter/form) in your documentation? If YES, move to question 3. If NO, ask for permission (OR use royalty free/your own original graphic) and if permission is granted, include the permission in your documentation.

2B) Is the graphic royalty free, or did you create your own graphic? If YES, cite the royalty free graphic OR your own original graphic properly in your documentation.

CHAPTER ADVISOR: Sign below if your student has integrated any graphics into his/her competitive event solution.

I, William Holler (chapter advisor), have checked my student's solution and confirm that the use of graphics is done so with proper permission and is cited correctly in the student's documentation.

3) Does your solution to the competitive event use another's thoughts or research? ☑ YES ◯ NO

If NO, this is the end of the checklist.

If YES, have you properly cited other's thoughts or research in your documentation? If YES, this is the end of the checklist.

If NO, properly cite the thoughts/research of others in your documentation.

CHAPTER ADVISOR: Sign below if your student has integrated any thoughts/research of others into his/her competitive event solution.

I, William Holler (chapter advisor), have checked my student's solution and confirm that the use of the thoughts/research of others is done so with proper permission and is cited correctly in the student's documentation.

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