Improving Mother Nature: Maximize Storm Water Runoff for Irrigation

Brief Description:

In this lesson, students will learn about the specific needs of plants, design a rainwater irrigation system and test the effectiveness of the system. A standard plot of garden plants will be exposed to the rain water delivery systems designed by students. Students will then measure the growth of their plants irrigated by different systems.

Objective:

Students will be able to:

1. Use scientific techniques to determine the effectiveness of rain delivery systems by measuring plant growth.
2. Apply measurement techniques, evaluate data, make comparisons and report on the implications based on their results.

Time:

Introduction: 30 minutes
Activity 1: 60 minutes
Activity 2: 120 minutes
Activity 3: 30 minutes
Activity 4: Depends on if in-class or at-home assignment

Materials Needed:

The supplies needed for this activity will vary from project to project. Below is a list of useful items students might want to obtain. Recycled or upcycled materials should be used whenever possible. Hardware stores often offer donations for school garden projects.

- Plastic containers (milk jugs, juice containers, salad containers, soda bottles, laundry soap containers, etc.)
- PVC pipe
- Plumbers tape
- Funnels
- Duct tape
- Nails
- Screws
- Garden string
- Gravel
- Hoses
- Tubing
- Zip ties
- Wicking material (cotton, twine, felt)
- Plastic net baskets
- Rain gutters
- Garden stakes
- Plastic bags
- Buckets
- Plastic/wooden/metal barrels/tanks
- Soil
- Plastic straws
- Screens (for filtering)
- And any other landscaping materials available to improve aesthetics and elevate apparatus to allow for gravitational design enhancements
- For advanced projects, consider plumbing supplies as well

Florida Standards:

SC.912.N.1.1, SC.912.N.1.3, SC.912.N.1.4, SC.912.N.1.6, SC.912.N.1.7, SC.912.N.3.5, SC.912.E.6.6, SC.912.E.7.1, SC.912.L.14.7, SC.912.L.14.53, SC.912.L.17.16, SC.912.L.17.17, SC.912.L17.20, SC.912.L.18.2, SC.912.L.18.7, SC.912.L.18.12, SC.912.L.18.7. (SC.7.N.1.3, SC.7.N.1.4, SC.8.L.18.1, SC.8.N.1.2, SC.8.N.1.3, SC.8.N.1.4), LAFS.910.RST.1.3, LAFS.910.WHST.2.6, LAFS.910.WHST.3.7, LAFS.910.WHST.3.8, LAFS.910.WHST.4.10, LAFS.1112.RST.1.3, LAFS.1112.WHST.2.6, LAFS.1112.WHST.3.7, LAFS.1112.WHST.3.8, LAFS.1112.WHST.4.10 (LAFS.68.RST.1.3, LAFS.68.WHST.2.6, LAFS.68.WHST.3.7, LAFS.68.WHST.3.8, LAFS.68.WHST.4.10)

Tools:

Scissors, power drill, screw driver, saw, shovels, rake and hammer

Preparation:

- Determine the resources available for this activity. Will this be implemented on an existing school garden? Will temporary containers be used or will the school grounds be altered? What supplies, technology and donations are available? Can other departments such as physics, engineering or vocational be involved? If the Water Quality Extension Activity is implemented, how will the water quality tests be performed and paid for?
- Solicit students and parents as soon as possible for supplies: hoses, tubing, PVC pipe, plastic containers, other recyclables (egg cartons for seeds, salad containers, plastic milk jugs, or others scrap items for decoration).
- Determine the type of plant(s) you will be using for this activity (see Considerations and Safety Guidelines if a food crop will be used).

Background:

Difficulties in gardening are diverse, but the challenge of irrigation is foremost in planning and maintaining crops. Besides the challenge of delivering water to plants, fresh water is a valuable resource that must be conserved whenever possible. Maximizing rainwater runoff for irrigating plants saves money, reduces the runoff into storm water systems and conserves fresh water. School buildings are equipped with rainwater diversion systems, which can be converted into an irrigation system for a garden. Designs for rainwater irrigation will focus on recycling/upcycling scrap materials and can range from a simple tube adjacent to a drain pipe or more complicated tanks storing runoff for future use. The data on the effectiveness of the different systems will be collected over a month (or more) and the most effective system will be determined. Students will present their findings in a formal lab report which includes graphical data, comparisons between irrigation systems, and an analysis focusing on conservation of resources and the long-term recommendations for the irrigation systems of the school garden.

Considerations and Safety Guidelines:

No alterations should be made to school property (even temporary) without first gaining permission from school administration and grounds maintenance personnel. When using recycled/upcycled materials, ensure proper sanitary measures are taken and none of the materials are procured from unsafe or unsanitary conditions. Additionally, if these techniques are to be implemented on food crops, students and teachers should carefully read *Rain Barrels Part IV: Testing and Applying Harvested Water to Irrigate a Vegetable Garden*, published by Rutgers, the State University of New Jersey (2013) and make proper determinations (see also Water Quality Extension Activity*). If water quality is questionable, use decorative non-food plants for this experiment. Students can design a rainwater catch system that does not come from any school structure roofs.

Introduction:

Introduce the project to the students and provide examples to get them interested in what they will be doing. Small scale examples can be brought into the classroom, students can read articles, or the class can be shown a video. If there is a school garden on site, ensure students are familiar with its location and proximity to drain spouts. There are numerous YouTube videos and instructional websites but below are a few examples:

Video examples:
This Old House rain collections installation: http://www.thisoldhouse.com/toh/video/0,,20794278,00.html
Rain Gutter Grow System: https://www.youtube.com/watch?v=GRQzhFBCot4
Rain barrel collection system: http://www.grownyc.org/openspace/rainwater-harvesting

Web articles:
'Gardening with Rainwater': http://www.bbg.org/gardening/article/gardening_with_rainwater
'How to Harvest Rainwater': http://www.gardengatemagazine.com/52droughttolerant/

Activity 1: Background Knowledge

1. Discuss with the class, plant structure and function. Use the *Plant Anatomy and Physiology Background Worksheet* to enable the students to organize this information. Depending on the scope and sequence of a particular county, this material will consist of some review and some new material for a biology or environmental science class. Students should work in groups to complete as much as possible on their own following a lecture, reading, or video.

Plant structure video:
https://www.youtube.com/watch?v=zHp_voyo7MY

Capillary action videos:
https://www.youtube.com/watch?v=y-h_qGhgtno,
https://www.youtube.com/watch?v=VXo-wLR8Aic

Plant Nutrition and Transport:
https://www.youtube.com/watch?v=bsY8j8f54I0

Activity 2: Research and Planning

1. Place students into groups. Each group will construct a small container self-watering system as shown in the pictures below. This will give students an idea of what is needed when designing their own system. Note: You can give the students the supplies and let them design their own small-scale self-watering system, but this activity is just to give them an idea of possible larger versions.
2. In groups give students time in class to research and plan their own designs for rainwater irrigation systems.

Improving Mother Nature: Rainwater Irrigation System Proposal is a suggested format for students to organize their plan. By the end of this activity they should have established the following:

- Type of plant(s) they will be using
- A hypothesis stating how they think their system will aid in plant growth
- Location and scale of irrigation system (small containers or large systems using school roof run off)
- Supplies they will need to build their system and how they will obtain their supplies

Figure 1: Supplies for a small scale container planter: strawberry baskets, seeds, three salad containers, scissors, marker, cheese cloth and twine. Not pictured are the green straws used to connect the wicking twine from the reservoir container to the plant container.

Figure 2: Assembled system has twine woven in the basket under the cheese cloth and up into the basket to serve as an automatic watering system.

Figure 3: Upper container serves as the catchment from a spout. A large hole in the lid below allows water to drain from the catchment which has small holes to filter debris.

Figure 4: Soil and seeds have been added to the baskets.

Figure 5: Water is poured into the catchment to ensure proper operation.

Figure 6: Seeds have sprouted and growth can be measured

- A diagram or model of their system
- A procedure for setting up their system and measuring the growth of their plants
- A schedule and data table for their measurements
- Description of methods for control comparison
- List of safety precautions

Activity 3: Construction

1. After the design has been approved, instruct the students to assemble their systems in class or at the locations where they will be implemented.
2. Have students bring extra supplies and tools in case they need to modify their irrigation systems.
3. Provide students with access to water so they can test the functionality of their design.
4. If they need to make modifications, remind them to update their proposal diagram, procedure and material list to reflect their modifications.
5. Ensure the control replicates are established at the same time and given the same amount of water as the experimental ones.
6. Instruct the students to take initial measurements of their plants (if seedlings are used). If they are planting seeds, wait until they have sprouted and the students have something to measure.

Data Collection Recommendations:

1. Control replicate plants can be used for more than one group of students. These plants should be in the same location as the experimental plants but with no rain water irrigation system applied. If the test plants are in a container then the control plants should be in a similar container. If test plants are in the ground then control plants should also be in the ground in a similar location.
2. When taking measurements of plant growth, students can use a piece of string to trace the length from the base of the stem above ground to the tallest/longest portion of the plant. They will then measure the string to ensure accuracy and minimize damage to the plant.
3. Weather conditions should be noted so students can analyze their results based on weather patterns.
4. The data collection frequency will vary depending on the type of plant and if they started as seeds or small plants. Depending on how fast the plants grow, data collection will be more or less frequent. Suggested collection times might be the last 20 minutes of class every Friday.
5. Each group member needs to keep a copy of the data sheet. If a person is absent, the other members of the group should still be able to collect data.

Activity 4: Report Writing

1. The students' final product will be a report comparing the growth of their experimental plants to the growth of the control as well as the growth of the other groups' plants. When data collection has finished, each group will share their results with the class and create a lab report on their findings. The reports should include:
   - **Hypothesis:** An hypothesis indicating how their irrigation system will aid in plant growth.
   - **Materials:** A list of all materials used.
   - **Procedure:** A detailed, step-by-step procedure of their experiment.
   - **Data:** A data table of the experimental and control plant measurements, and a line graph comparing the experimental and control plants' growth. Data tables and graphs comparing the plant growth of each group. Replicate plant growth measurements should be averaged.
   - **Results:** A description of the results indicating how the experimental plant growth compares to that of the control as well as comparisons between different irrigation systems.
   - **Analysis:** Using reference material, the results should be explained and rationalizations for outcomes should be made based on research data and the obtained experimental data.
   - **Discussion:** Students should make recommendations for improving their designs and indicate large-scale benefits of using recycled materials to conserve natural resources.
   - **References:** All resource material should be cited in APA format including in-text citations.

Water Quality Extension Activity:

When food plants are used, water quality issues must be considered. It has been determined that toxic substances may be present in rainwater runoff from roofs and other surfaces (Bakacs, et al., 2013).

This presents an opportunity for students to learn about the importance of water quality. This extension would be ideal to conduct along with irrigation system experiments or on an existing rainwater reclamation system. Opportunities for advanced science fair projects focusing on risk assessment could be implemented by students. The EPA published guidelines for water reuse in EPA, Guidelines for Water Reuse 2012. These guidelines include acceptable limits for toxicants and recommendations for filtering and safety.

Considerations and Safety Guidelines:

Fecal coliform tests must be performed within eight hours of

collection for accurate results. Schools equipped with microbiology labs would be ideal to analyze samples. Alternatively, samples could be transported to a local college microbiology lab for analysis. If samples are not analyzed by the school or a collaborating college, they could be sent to a private lab. However, the cost for a private lab analysis is substantial and fecal coliform samples would have to be hand delivered.

Once toxicity levels of rainwater are determined, students could use the EPA guidelines to make recommendations for filtration systems and advise the school on the use of rainwater for food plants. A study of this nature would be at a college or professional level.

Extension Activity Resources:

- Commercial labs in FL: http://www.flenviro.com/fsestemp3.html
- EPA Guidelines for Water Reuse: http://www.lacsd.org/civicax/filebank/blobdload.aspx?blobid=2184
  - EPA documents online: http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf

Extension Activity Standards:

- SC.912.N.1.1, SC.912.N.1.3, SC.912.N.1.4, SC.912.N.1.6, SC.912.N.1.7, SC.912.N.3.5, SC.912.L.17.13, SC.912L.17.14, SC.912.L.17.15, SC.912.L.17.16, SC.912.L.17.17, SC.912.L.4.1, SC.912.4.2, SC.912.P.8.11, SC.912.P.8.13, SC.912.P.8.7, SC.912.P.8.9.

References:

Bakacs, M., Haberland, M., & Yergeau, S. (2013, December). Rain Barrels Part IV: Testing and Applying Harvested Water to Irrigate a Vegetable Garden. Retrieved from https://njaes.rutgers.edu/pubs/fs1218/

Improving Mother Nature: Maximize Storm Water Runoff for Irrigation

Sample Pre-Post Test Assessment

Directions: Choose the best answer for each of the questions below.

1. In order to make a determination about the effectiveness of a garden system, which of the following should take place?
   a. Different methods of gardening are implemented and the best looking system is considered the most effective.
   b. Data in the form of measurements collected over time is compared and a determination about the effectiveness of a system is made based on the results.
   c. Students and teachers vote on the garden system they think is the most effective and the one with the most votes will be determined to be the best.
   d. The system that is the cheapest will be considered the most effective because cost is always an issue.

2. Which of the following statements correctly describes the function of the transport system in plants?
   a. The transport system in plants moves water and nutrients throughout the plant's structure to facilitate growth.
   b. The transport system in plants moves water only to the leaves.
   c. The transport system in plants moves nutrients only from the roots to the rest of the plant.
   d. The transport system in plants moves sunlight from the leaves to the roots.

3. The general formula for photosynthesis is:
   a. sunlight + water + carbon dioxide -> oxygen + methane
   b. sunlight + water + carbon dioxide -> oxygen + water
   c. sunlight + nitrogen + carbon dioxide -> oxygen + sugar
   d. sunlight + water + carbon dioxide -> oxygen + sugar

4. Chose the phrase below that correctly describes the movement of water through plants.
   a. Active transport moves water from the leaves to the stems.
   b. Diffusion is the movement of water from the leaves to the atmosphere.
   c. Water moves through osmosis into the roots and through capillary action is transported to the rest of the plant.
   d. Osmotic pressure is only present when nutrients are not present in the soil.

5. The cells of a plant are rigid due to the presence of water. Chose the term describing this.
   a. Osmotic pressure
   b. Active transport
   c. Photosynthesis
   d. Transpiration

Plant Anatomy and Physiology Background Worksheet

Name _____

Plant Structure:

1. What are the three principal organs of plants?

   a. _____ b. _____ c. _____

Stem Structure and Function:

2. What are the two important functions of stems?

   a. _____ b. _____

3. What is transpiration?

4. What does the transport system of stems do?

Roots:

5. Circle the letter of each sentence that is true about a function that roots perform.
   a. They anchor plants in the ground.
   b. They compete with other plants for sunlight.
   c. They absorb water and nutrients from soil.
   d. They hold plants upright.

6. Water enters the plant through the large **surface area** provided by the _____

7. What are two functions of a plant's roots?

   a. _____ b. _____

8. True or False? The ingredients of a soil can determine what kinds of plants grow in it.

9. Circle the letter of each sentence that is true about **active transport** of minerals in roots.
   a. Water molecules move into the plant by active transport.
   b. ATP is the source of energy used to pump mineral ions from the soil into the plant.
   c. The cell membranes of root hairs contain active transport proteins.
   d. Using active transport, a root actually pumps water into the plant.

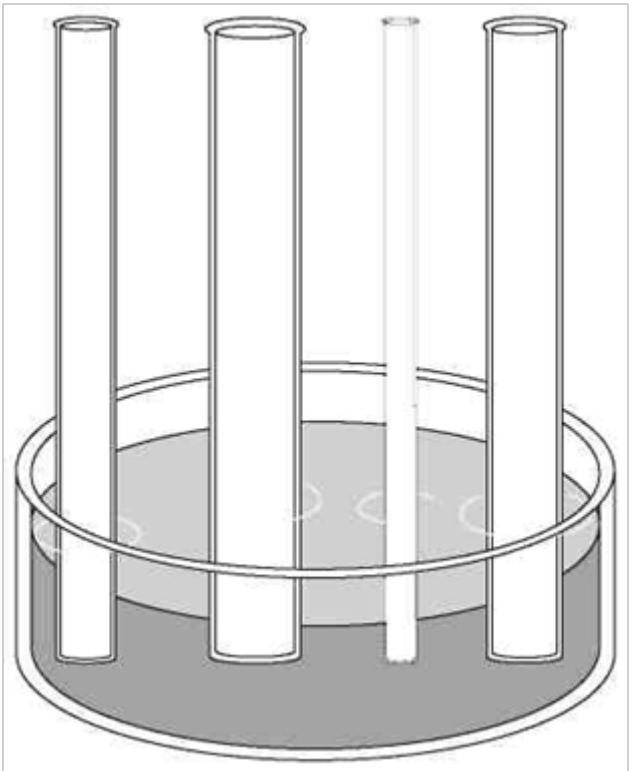
Transport in Plants - Water Transport:

10. How can water move from the roots to the rest of the plant?

11. What combination of factors provides enough force to move water through the tissue of even the tallest plant?

12. The tendency of water to rise in a thin tube is called _____

13. How does the thinness of a tube affect how high water will rise because of **capillary action**? Show your answer by drawing how high water would rise in each of the tubes on the illustration.



14. What keeps a plant's leaves and stems rigid?

_____

15. How does the loss of **osmotic pressure** in leaves slow down the rate of transpiration?

Leaves and Nutrient Transport:

16. The principal organs in which plants carry out **photosynthesis** are the _____

17. How do the carbohydrates produced in photosynthesis get to the rest of the plant?

18. How is the water content of a leaf kept constant?

Define the following vocabulary terms:

19. surface area

20. active transport

21. capillary action

22. **osmotic pressure**

23. **photosynthesis**

24. Draw and label a diagram of a plant including **roots**, **leaves** and **stems**. Use a blue arrow to show how water moves from the soil into the plant. Use a red arrow to show how carbohydrates created during photosynthesis move from the leaves to the rest of the plant.

Plant Anatomy and Physiology Background Worksheet: Answer Key

Plant Structure:

1. What are the three principal organs of plants?
   a. **Roots** b. **Stems** c. **Leaves**

Stem Structure and Function:

2. What are the two important functions of stems?
   a. **Transport materials throughout the plant** b. **Hold the leaves up to the sun**

3. What is transpiration?
   Loss of water from the leaves of the plants through evaporation, helping to cool the plant

4. What does the transport system of stems do?
   Moves water and nutrients from the roots to the rest of the plant

Roots:

5. Circle the letter of each sentence that is true about a function that roots perform.
   (a.) They anchor plants in the ground. b. They compete with other plants for sunlight.
   (c.) They absorb water and nutrients from soil. (d.) They hold plants upright.

6. Water enters the plant through the large **surface area** provided by the **roots**

7. What are two functions of a plant's roots?
   Anchoring to the ground, food storage, nutrient and water absorption

8. True or False? The ingredients of a soil can determine what kinds of plants grow in it. **True**

9. Circle the letter of each sentence that is true about **active transport** of minerals in roots.
   (a.) Water molecules move into the plant by active transport.
   (b.) ATP is the source of energy used to pump mineral ions from the soil into the plant.
   (c.) The cell membranes of root hairs contain active transport proteins.
   (d.) Using active transport, a root actually pumps water into the plant.

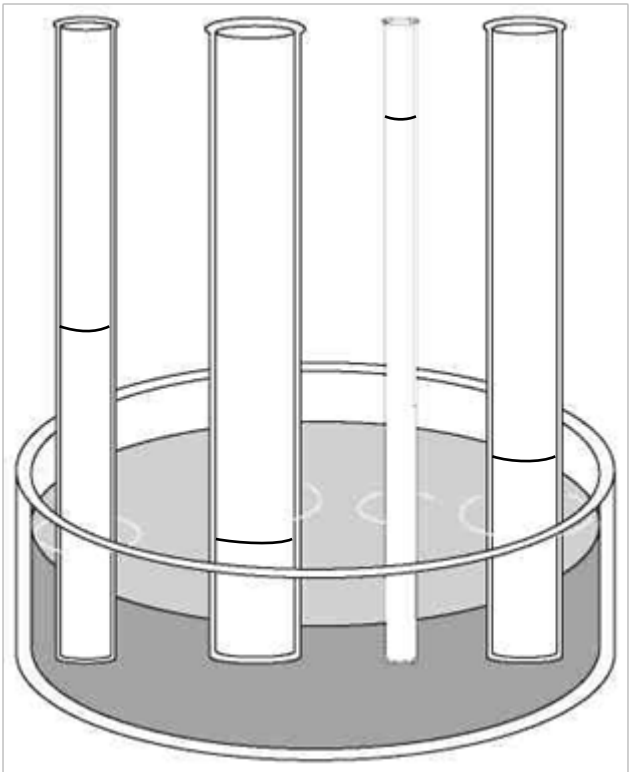
Transport in Plants - Water Transport:

10. How can water move from the roots to the rest of the plant?
    Capillary action combined with active transport causes water to move from the roots to the rest of the plant

11. What combination of factors provides enough force to move water through the tissue of even the tallest plant?
    Water cohesion and adhesion

12. The tendency of water to rise in a thin tube is called **capillary action**

13. How does the thinness of a tube affect how high water will rise because of **capillary action**? Show your answer by drawing how high water would rise in each of the tubes on the illustration.



14. What keeps a plant's leaves and stems rigid?
osmotic pressure

15. How does the loss of **osmotic pressure** in leaves slow down the rate of transpiration?
With less pressure from water at the surface of the leaves, less water will evaporate

Leaves and Nutrient Transport:

16. The principal organs in which plants carry out **photosynthesis** are the
leaves

17. How do the carbohydrates produced in photosynthesis get to the rest of the plant?
Active transport

18. How is the water content of a leaf kept constant?
Active transport in the roots and transpiration in the leaves

Define the following vocabulary terms:

19. **surface area – the area of a structure in contact with the surrounding environment**

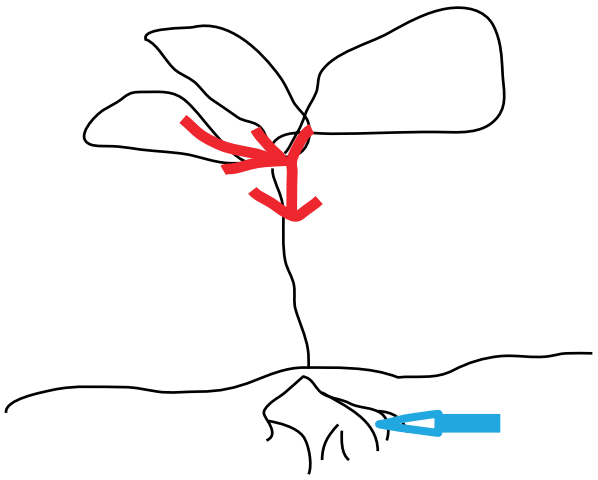
20. **active transport – an energetic process (using ATP) that moves ions and nutrients across cell membranes**

21. **capillary action – the combination of adhesion and cohesion allowing water to move against gravity through a tube**

22. **osmotic pressure – The pressure exerted by water on the cell membrane maintained by the osmotic movement of water form areas of high concentration to areas of low concentration**

23. **photosynthesis – The process of transforming carbon dioxide, sunlight, and water into carbohydrates and oxygen**

24. Draw and label a diagram of a plant including **roots**, **leaves** and **stems**. Use a blue arrow to show how water moves from the soil into the plant. Use a red arrow to show how carbohydrates created during photosynthesis move from the leaves to the rest of the plant.



Improving Mother Nature: Rainwater Irrigation System Proposal

Name(s) _____

Plant Information:

Type of Plant(s)	Grown from seed?	Ideal light conditions	Ideal moisture conditions	Number of replicate plants for experiment / control

Hypothesis: How will your rainwater system aid in plant growth?

Test Plot Area Information:

Container?	Size of standard plot (meters)	Approximate hours of sunlight daily	Description of drainage at this location	Soil type (sand, clay, rocky)

List of supplies needed to construct rainwater irrigation system:

Procedure for set up and planting:

Description of control conditions and location:

Diagram (on a separate sheet of paper or on the back of this paper) of irrigation system (include measurements using meters), including drawings of plants.

Growth Data

(attach additional sheets if necessary)

Date / time									
Weather									
Experimental Replicate 1 height (m)									
Experimental Replicate 2 height (m)									
Experimental Replicate 3 height (m)									
Experimental Replicate 4 height (m)									
Experimental Replicate 5 height (m)									
Control Replicate 1 height (m)									
Control Replicate 2 height (m)									
Control Replicate 3 height (m)									
Control Replicate 4 height (m)									
Control Replicate 5 height (m)									

Safety Concerns: When experimenting on food crops, consider water quality issues associated with roof water runoff. Ensure all building materials are sanitary and do not present any hazards. List any precautions necessary for constructing irrigation system (gloves, eye protection, etc.).