
Aquaculture Curriculum Guide

Plant Aquaculture Module

Problem Areas:

Determining Basic Concepts of Plant Aquaculture

Producing Aquatic Food Plants in Saltwater

Producing Aquatic Food Plants in Fresh Water

Using Aquatic Plants for Special Purposes

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A Project of
The National Council for Agricultural Education
Alexandria, Virginia

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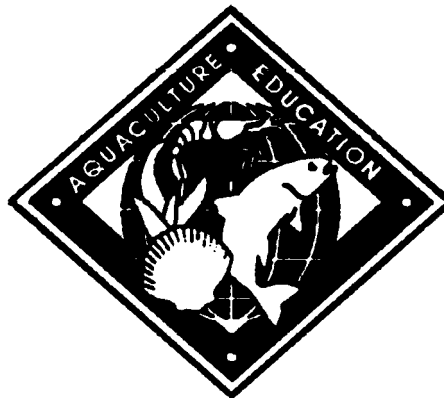
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1995 Preliminary Edition

Plant Aquaculture

AQUACULTURE CURRICULUM GUIDE

YEAR TWO SPECIES MODULE



Project of
The National Council for Agricultural Education
Alexandria, Virginia

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United States Department of Agriculture

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Overview

To The Teacher

The Plant Aquaculture module is designed to assist students in developing knowledge and skills in plant aquaculture production. The module assumes that the student has completed Modules I-V in year one of the Aquaculture Curriculum produced by the Council. The concepts presented are appropriate for upper level high school or community/junior college students.

Plant aquaculture is a very young enterprise in the United States. With the exception of some coastal states and Hawaii, little plant aquaculture can be found in this country. The material presented in this module, therefore, often relates practices used in other countries that might be possibly used more extensively in the US. Students should be made aware that much of the plant aquaculture in the US. is considered exploratory. Students should experiment with these concepts, but, in almost all cases, not be encouraged to anticipate profitable results until markets and production procedures are further developed. It should be noted, however, that extensive plant aquaculture is practiced successfully in other parts of the world (and some places in the US.) and has potential in the US. both as a way for aqua farmers to supplement their existing operations and to develop stand-alone operations. Plant aquaculture should continue to increase as this potential is further developed.

Three areas that are not discussed in this module are rice production, hydroponics, and aquaculture/irrigation systems. Rice is generally considered an agronomic crop that just happens to be able to grow in water - the water is merely a method of weed control. Hydroponics is generally considered a horticultural enterprise, with vegetables as the primary crop. Aquaculture/irrigation systems use nutrient-rich water from aquaculture systems to irrigate agronomic crops, thus getting two used from the scarce water supplies available in certain parts of the US., particularly the western states. These three enterprises are important, but are not specifically involved in the culture of aquatic plants.

Description: The module consists of the following four problem areas:

Module: Plant Aquaculture

Problem Areas: Determining Basic Concepts of Plant Aquaculture
Producing Aquatic Food Plants in Saltwater
Producing Aquatic Food Plants in Fresh Water
Using Aquatic Plants for Special Purposes

The module is designed for 15-26 hours of instruction. You should adjust this length based on the availability of examples of plant aquaculture production in your local area. More time maybe needed where production is prevalent and more activities are carried out.

Objectives: The objectives for each problem area are given below.

A Determining Basic Concepts of Plant aquaculture
Define plant aquaculture
Identify the major plant aqua crops
Describe scientific concepts related to aquatic plant production
Describe economic/production factors related to plant aquaculture

B. Producing Aquatic Food Plants in Saltwater
Describe the primary species produced

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Describe cultural requirements for saltwater plant aqua crops
Discuss methods of culture for saltwater plant aqua crops
Identify nutritional qualities of saltwater plant aqua crops
Identify marketing strategies for saltwater plant aqua crops

C. Producing Aquatic Food Plants in Fresh Water

Describe the primary species produced
Describe cultural requirements for freshwater plant aqua crops
Discuss methods of culture for freshwater plant aqua crops
Identify nutritional qualities of freshwater plant aqua crops
Identify marketing strategies for freshwater plant aqua crops

D. Using Aquatic Plants for Special Purposes

Describe the use of aquatic plants for production of phycocolloids
Describe the use of aquatic plants for livestock feed and fertilizer
Describe the use of aquatic plants for feed for other aquacrops
Describe the use of aquatic plants for wastewater treatment
Describe the use of aquatic plants for ornamental purposes

Format:

This module was written in a popular format used widely by agriculture educators. The introduction to each problem area teaching plan contains the purpose/goal of instruction, objectives for student performances upon completion of instruction, and essential and additional instructional resources needed to teach the unit.

The content and procedures section contains an interest approach for developing student interest in the topic. It also contains a summary of the content of the plan and recommended teaching techniques for teaching. A problem area test and transparency masters are provided.

Reference Materials:

The following is a list of all reference materials cited in this module, Follow each book is a source from which the publication may be obtained, if available. (Note: Materials are listed alphabetically by last name of the first author of the publication.)

Taxonomy of Economic Seaweeds (Report No.T-CSGCP-018)(1988) by Isabella 1A. Abbot (Ed.) is available from: The California Sea Grant College Program, University of California, A-032, La Jolla, CA 92093-0232.

Aquaculture; The Farming and Husbandry of Freshwater and Marine Organisms (1972) by John E. Bardach, John H. Ryther, and William O. McLarney is available from: John Wiley and Sons, Inc., 605 Third Avenue, New York, NY 10158.

Seaweeds and Their Uses (1970) by V.J. Chapman is available from: Methuen and Co., Ltd., 11 New Fetter Lane, London, England, EC4.

Underwater Farming (1988) by George S. Fichter is available from: Pineapple Press, Inc., P.O. Drawer 16008, Sarasota, FL 34239.

Mariculture of Red Seaweeds (Report No, T-CSGCP-002) (1981) by Judith E, Hansen, Julie E. Packard, and W.T. Doyle is available form: The California Sea Grant College Program, University of California, A-032, La Jolla, CA 92093-0232.

Hawaii Watecress Production (Research Extension Series 088) (1987) by John J. McHugh, Steven K. Fukuda, and Kenneth Y. Takeda is available from: College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, HI 96822.

Introduction to Aquaculture (1992) by Matthew Landau is available from: John Wiley and Sons, Inc., 605 Third Avenue, New York, NY 10158.

Aquaculture: An Introduction (1992) by Jasper S. Lee and Michael IE. Newman is available from: Interstate Publishers, Inc., P.O. Box 50, Danville, IL 61834.

Production, Trade and Utilization of Seaweeds and Seaweed Products by J. Naylor is available from: Food and Agriculture Organization of the United Nations, Publications Division, Via delle Terme di Caracalla, 00100, Rome, Italy.

Introduction to Freshwater Vegetation (1984) by Donald N. Riemer is available from: AVI Publishing Company, Westport, CT.

A Field Guide to Economically Important Seaweeds of Northern New England (1992) by Susan K. White is available from University of Main/University of New Hampshire Sea Grant Advisory Program.

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Teaching Plan:

Module: Plant Aquaculture

Problem Area: Determining Basic Concepts of Plant Aquaculture

Estimated Time: 3-5 hours

Purpose/Goal: The goal of this problem area is to develop knowledge of the basic concepts that undergird the production and growth of plants in water. The major plant aquacrops are presented, as well as plant science and economic concepts that relate to plant Aquaculture production.

Learning Objectives: Upon completing this problem area, students will be able to:

define plant Aquaculture
identify the major plant aquacrops
describe scientific concepts related to aquatic plant production
describe economic/production factors related to plant Aquaculture

(Use transparency TM 1 to inform students of the objective of the lesson.)

Instructional Resources: The following instructional resources are needed to complete this problem area:

Essential:

Copies of transparencies made from masters in this teaching plan.

The following books:

Aquaculture: An Introduction by Lee and Newman; and

Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms by Bardach, Ryther, and McLamey.

Additional:

The following books:

Production, Trade and Utilization of Seaweeds and Seaweed Products by Naylor;

Introduction to Aquaculture by Landau; and

Seaweeds and Their Uses by Chapman.

Hawaii Watercress Production by McHugh, Fukuda, and Takeda.

Content and Procedure

Preparation (Interest Approach):

To develop student interest in this module, complete one or more of the following activities:

1. Bring a sample of water from an aquaculture facility class. Describe the characteristics of the water, including different materials that can be found, such as oxygen, carbon dioxide, ammonia, nitrates, nitrites, dissolved solids, pH, potassium, phosphorus, iron and other minerals, etc. Relate these to the needs of a plant. Lead discussion to the possibilities of growing plants in this water.
2. Have students read Chapter 14 (oral least the introductory paragraphs) in Aquiculture -An Introduction by Lee and Newman. Discuss the possibilities of plant aquaculture in the local area.
3. Take students to a local production facility that either produces aquatic plants or has the potential to do so.
4. Invite a local producer of aquatic plants to class demonstrate some of the plants and discuss the procedure. (Use only if activity three is not possible.)

Presentation:

A What is plant aquaculture?

Ask students to give examples of plant aquaculture. Discuss the differences between “culturing” and “gathering.”

Plant aquaculture is the culture of aquatic plants as food for humans or for other special purposes,

Plant aquaculture is much more prevalent in other countries than in the U.S.

Use transparency TM 2

Production may be in a monoculture or polyculture (with other plants or animals) system

Ask students to consider why plant aquaculture is more prevalent in other countries.

Possible answers: 1) Other countries have been practicing aquaculture in general much longer; 2) Population density is much larger, with less area per capita for traditional agriculture; 3) A higher percentage of people live close to coastal areas; 4) People in these countries have established a taste for plant aquacrops over the years.

Other types of production include phycocolloids, ornamental uses, animal feeds, mulches and fertilizers, and wastewater treatment.

R What are the major aquacrops?

Bring examples of plant aquacrops from the local area. (Watercress and Chinese waterchestnuts are available in most supermarkets.)

1. Saltwater Food Plant Aquacrops

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- a. Common Name: Brown Algae; Scientific Names: *Undaria pinnatifida*, *Macrocystis pyrifera*, *M. integrifolia*
Other names: kelp (Europe and U.S.); wakame (Japan)
Use student handout H 1. Student may need to review the extended scientific classification for these plants:
Kingdom- *Plantae*; Brown Algae: Division= *Phaeophyta*, Class- *Phaeophyceae*,
Order- *Laminariales*, Family- *Alariaceae*(*U. pinnatifida*) Family- *Lessoniaceae*
(*Macrocystis spp.*)
- b. Common Name: Red Algae; Scientific Names: *Porphyra spp.*, *Gelidium spp.*, *Gracilaria*

Other Names: purple laver (Europe and U.S.), nori (Japan)
Red Algae: Division - *Rhodophyta*; Class- *Rhodophyceae*; Order- *Bangiales*;
Family= *Bangiaceae*
- c. Common Name: Green Algae; Scientific Names: *Monostroma spp.*, *Enteromorpha spp.*
Other Names: green laver Z(Europe and U.S.), aonori (Japan)
Green Algae: Division- *Chlorophyta*, Class- *Chlorophyceae*, Order- *Ulvales*, Family-
Monostromataceae

2 Freshwater Food Plant Aquacrops

- a. Common Name: Watercress, Scientific Name: *Nasturtium officinale*
Watercress and Chinese waterchestnuts are both in the *Anthrophyta* division and
Magnoliopsida class
Watercress: Order- *Cruciferales*, Family - *Cruciferae*
Waterchestnuts: Order- *Myrtales*, Family- *Trapaceae*

3. Specialty Plant Aquacrops

- a *Phycocolloid* Production (*agar carrageenan*, and *algin/alginates*)
Red Algae: *Geldidium spp.*, *Gracilaria spp.* Brown Algae: *Laminaria spp.*, *Macrocystis spp.*
- b. Animal Feeds
Green Algae: *Spirulina spp.*; Red Algae: *Palmaria palmata*; Brown Algae: *Alaria spp.*; Duckweed:
Lemna spp., *Spirodela spp.*, *Wolffia spp.*, *Wolffiella spp.*; Water spinach: *Ipomoea reptans*
Optional: Assign a plant to each student, starting with the most common, and have students
give oral reports about each plant.
- c Wastewater Treatment
Water Hyacinth: *Eichhornia crassipes*
- d. Mulches and Fertilizers
Brown Algae: *Ascophyllum spp.*, *Fucus spp.*, *Sargassum spp.*, *Laminaria spp.*, *Ecklonia spp.*
- e. Ornamentals
Cattail: *Typha latifolia*, *T. angustifolia*
Arrowhead: *Sagittaria spp.*

C. What are the primary scientific concepts pertaining to aquatic plant productions?

Use oral questioning to determine existing student knowledge of these concepts.

1. Photosynthesis -The process by which plants use light energy (in the presence of chlorophyll) to convert carbon dioxide (CO₂) and water (H₂O) into carbohydrates (C₆H₁₂O₆) which can then be used for energy for growth and reproduction. By-products of this process are water and oxygen (O₂).

Use TM 3

The formula for photosynthesis is: $6\text{CO}_2 + 12\text{H}_2\text{O} \xrightarrow{\text{light -chlorophyll}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{H}_2\text{O}$

Chlorophyll is also the pigment which gives the plants their green color. Other pigments, such as xanthophylls, phycobilins, and carotenes, give plants a reddish or brownish color,

2. Respiration - The process by which plants convert carbohydrates and oxygen to energy (in the form of ATP, adenosine triphosphate). By-products of this process are carbon dioxide and water.

Use TM 4. These concepts and or their effects can be demonstrated using Application Activity 4 at the end of this plan.

The formula for respiration is: $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \text{ -----} > 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy}$

3. Nutrient Uptake -Aquatic plants obtain most of their nutrients from the water in which they are grown. This factor makes them useful with polyculture with animal aquacrops because they use the various forms of nitrogen wastes (NH_3 , HO_2 , and NO_3) produced by the animals. This ability also makes plants useful in wastewater treatment.

Use TM 5

4. Reproduction - Plants can reproduce sexually or asexually. The aquatic plants described in this module can be reproduced using either method.

Use TM 6

Sexual reproduction involves the fusion of gametes (sex cells) followed by meiosis (cell division). This fusion of gametes may result in a zygote (new plant) or a seed, which must germinate to produce a new plant.

Bring examples of these plants to class and demonstrate the process of propagation used with each type. (Use Application Activity 6 at the end of this plan, if possible.)

Asexual reproduction includes any means other than sexual reproduction. This may include production of asexual spores, corms, shoots, or bulbs. It may also involve mechanical reproduction, such as cuttings.

- a. Algae - Mature algae plants, called sporophytes, release spores that become microscopic plants. These plants then produce gametes with fuse and produce new plants. Algae may also release asexual spores, called monospores, which then become new plants.
- b. Watercress - in nature, watercress produces gametes which fuse to form a seed. It can also reproduce by sprouting shoots that result in new plants. In commercial production, however, mechanical reproduction is used. Terminal cuttings are used to start new plants.
- c. Chinese Waterchestnuts - Chinese waterchestnuts reproduce by developing corms, fleshy underground stems. Each corm can then be removed from the parent plant and planted to develop into a new plant. One parent plant can produce hundreds of these new corms in a growing season. (This is also the part of the plant that is eaten, so most corms are not used for reproduction.)

D. What economic/production factors must be considered when starting a plant Aquaculture operation?

Bring in a resource person with experience starting up a plant aquafarm, or if not available, someone who has started any type of aquafarm. Use TM 7 to complement the resource parson's comments if necessary.

1. Marketability- The ability to sell a plant aquacrop should be the first consideration when deciding whether or not to produce it. Several factors must be considered. These include the following:

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- a Existing markets - How much of the aquacrop is currently being sold in the market area? Is the supply currently available to meet the demand? Can you produce a product of higher quality and/or at a lower price? As a producer, will you sell the product wholesale or retail?

Use Application Activity 1 to reinforce market concepts.

- b. Market potential - Can advertising or promotional programs increase the existing market? How much promotion is needed? How much will it cost?
 - c Market stability- Does the market function year-round or is it seasonal? Can you produce the amount needed when it is needed? Would market size increase if the product was consistently available? Is the existing market a niche market that maybe taken over by larger suppliers if it develops into a larger market? How much storage is required and for how long?
 - d. Product development and delivery - Does the product require further processing after harvest? How much will it cost to deliver the product to the market? Will the buyer pay a premium for extra service required?
2. Site Selection - Once a market has been identified, the aquafarmer must determine an appropriate site for production. Of course, if a polyculture is planned with one or more animal aquacrops, then the facility may already be in place.

Have students nominate possible sites. Compare site characteristics to requirements for the different plant aquacrops. Visit one or two promising sites, if possible.

When planning a new facility, several factors may need to be considered. Examples include the following:

- a Algae - Since most species of algae are grown in saltwater, the most important criterion for site selection is a location in the ocean where the plants can be cultured. The primary competition for a location will be recreation and commercial uses. Many states have laws regulating the use of these waters and permits must be obtained before beginning production. These laws vary from state to state. The distance from the shore can also be an important criterion. Many types of algae only grow in shallow water. This means that the aquafarmer must either locate a site close to shore or build a substrate for the plants to attach themselves. If a site away from shore is selected, this distance will have to be traveled when placing plants, harvesting, and periodically checking plants. The farther out the site, the more it will cost to travel to it.
Most algae will be grown on structures placed in the water by the aquafarmer. Sometimes existing structures may be used to anchor the rafts or nets, such as an abandoned oil well platform or pier. The aquafarmer must take care to select a site that is unlikely to be damaged by boat or ship traffic or by vandalism.
- b. Watercress - Watercress requires a site with an ample supply of fresh, running water. Atypical watercress operation will use about one million gallons of water per acre per day.
The source of water will usually be a spring or artesian well. Pumping ground water would be too expensive.
Watercress also needs an ample supply of sunshine, moderately warm air temperatures, and water that contains nitrogen. A firm soil is needed because of the amount of water that will run over it.
- c Chinese waterchestnuts - Chinese waterchestnuts can be grown in most places in the southeastern United States. They grow best in a warm, humid climate, A site with sandy soil is a requirement for acceptable growth.
Chinese waterchestnuts can be grown in shallow raceways, flooded fields, or indoor troughs. These plants need warm water for most of the year.

Availability of utilities, particularly electricity, can also be an important consideration in site selection.

Ask students to think of other general site requirements. See if they can come up with utilities and access,