Planting out in the field. At destination, insertion of the close-knitted fibrous roots in a mud solution results in a flat rootplate, the mud filling in and adhering to the rootmass; these can be quickly planted in the field when placed up against 18 cm vertical cuts in the soil, made with a hoe. They establish themselves quickly, but sometimes need initial paper protection around the stems and, in arid climates, mulching.

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PROPAGATION OF PRAWNS AND PLANTS IN THE SAME ENVIRONMENT

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Abstract. Neotoma Enterprises is investigating the potential of combining aquaculture, hydroponics, and solar technologies. Our experimental and prototype polyculture systems demonstrate a significant net income increase per square foot of growing area over conventional aquaculture and plant propagation facilities. The use of solar collectors and a large volume of water for heat storage minimize system heating costs.

INTRODUCTION

Recent years have seen large increases in production and marketing costs for many nurseries. Petroleum products used in fertilizers, heating, and transportation have risen dramatically in price during the last ten years. Land prices and taxes, especially in areas near large metropolitan centers, often make expansion of a business economically unfeasible.

Our goals in developing polyculture systems are to increase production of marketable products from a given space, offer a diversity of products to minimize effects of market fluctuations, and reduce operating expenses to a level below that of a conventional greenhouse — all of which serve to increase profit potential.

In order for a single system to promote both plant and animal growth, the environmental parameters required for all species cultured must be met. These parameters include temperature, light, pH, oxygen, space, and nutrients. While it seems unlikely that optimal conditions can be achieved in all cases, it has proven feasible to create conditions where overall system production and profitability are increased over monoculture (independent plant propagation, or animal rearing) operations.

The high profit potential of a recirculating aquaculture-hydroponic system is due to the components being inherently complementary. The animals, which generate metabolic wastes (primarily ammonia), require water conditions where low levels of these products are maintained in order to thrive. The plants require these same elements and compounds at constant levels in order to remain healthy and grow at a profitable rate. Water circulation within a combined system carries the nutrient rich water from the prawns to the plants, where nutrients are removed, "purifying" the water before its return to the prawn culture tanks. A recirculating system has the added advantage of minimizing heat waste. The same solar-heated water is used to maintain acceptable temperature levels for both the plants and animals.

MATERIALS AND METHODS

A. Solar Energy Inputs

1. *Facility* — The greenhouse assoicated with our experimental systems makes available 1500 sq. ft. of floor space on three levels.

2. *Water Heater — Collection, Storage, and Distribution to Systems* — Solar panels supplemented when necessary by a wood-fired water heater maintain a water storage tank temperature in excess of 25°C. Heat is transferred from the storage tank to the culture system water by means of heat exchangers mounted in contact with the culture system. Differential thermostats which activate small circulating pumps maintain a constant preset temperature in the aquaculture and hydroponic componants.

B. Species Selection

The selection of the freshwater prawn, *Macrobrachium rosenbergii*, as the most likely animal candidate for the aquaculture component of a system is based on several factors.

These include known rearing technology, fast grow-out to market size, high market value, and a temperature range of 24° to 30°C (75° to 85°F.).

The temperature range for *Macrobrachium* allows a wide choice in selection of suitable plant species for culture in the hydroponic beds. Convection and radiation from the aquatic systems maintains greenhouse air temperature within an acceptable range for most tropical and semi-tropical species.

C. **Culture System**

Large *Macrobrachium* (6 to 10 per pound) require approximately 1 sq. ft. of substrate surface area per animal. This surface may be a tank bottom or a suspended substrate (such as plastic plant pots or flats). By using the suspension or stacking methods, several layers of prawns can be grown in the same floor space, thereby increasing total production.

Since the prawn is a nocturnal animal, no light is required in the tanks in which it is cultured. They can be located, for example, under a greenhouse floor or tables. The absence of light minimizes growth of algae in the system.

The aquaculture tanks may be constructed of any inert material such as aged concrete, fiberglass, or plastic-lined wood or metal. A maximum depth of 1 meter has proven acceptable. Oxygen levels required by the prawns are maintained in the tanks by means of aquarium airstones.

Seed starting flats with perforated bottoms are mounted on top of the prawn tanks 10 to 15 cm above the water level. Splash and mist created by the airstones keeps the medium in the seed flats warm, moist, and supplied with nutrients required as the plants begin to grow.

From the seed flats, the small plants are transferred to 2 in. pots, or to hydroponic growing beds. These beds may be mesh bags suspended in the aquaculture tanks, or separate tanks or troughs, again composed of inert material. The medium chosen for the hydroponic culture systems is mixed composition pea gravel, which serves well to support seedlings and cuttings. It is theorized that this medium may also provide some of the micronutrients and trace elements required by the plants.

The primary source of vitamins, micronutrients, and trace elements for the plants is found in the food provided to the prawns. While commercially available pelletized feeds have given acceptable prawn growth, the use of "live" foods such as vegetable material and fish processing wastes promotes better general health and growth, and are of significant value to the plants as well.

RESULTS AND CONCLUSIONS

It has proven technically feasable and economically profitable to culture prawns and plants in the same system. Prawn production at close to maximum levels can be attained. Plant production, while not at the levels demonstrated by chemically nutrified hydroponic systems, can still be expected at a level 30% above conventional propagation methods. The implementation of the stacking method (prawns below, plants above) requires no more floor space than a monoculture (aquatic or nursery) operation, while providing two marketable products instead of one.

Additional benefits of the solar-aquaculture-hydroponic system include:

1. Utilization of renewable resources as its driving force.
2. Labor intensive, but not requiring highly skilled labor for routine maintenance.
3. Construction from standard and readily available components.
4. Cost and energy effective.
5. Non-polluting (no discharge to the surrounding environment).
6. Water and energy conserving.
7. Adaptability to a wide range of plant and animal species, as well as geographical locations.

A multi-faceted system, such as the one described, is not without drawbacks. Of primary concern is the fact that many of the petroleum based pesticides currently used in nurseries are toxic to aquatic animals. Other factors which must be considered include the need for additional monitoring and control systems, meeting regulations concerning both animal and plant production, and the need of the culturist to have an understanding of both plant and animal biology.

Further development of biologically based pesticides should in the near future alleviate what appears to be the main problem. Rapid progress has been made in recent years in the development and application of alternative technologies. However, much experimental work has yet to be completed before large scale integrated alternative technology ventures can be considered anything other than high risk.

Current and predicted trends indicate continuity healthy markets for food and luxury or ornamental products. The business which can supply these markets, while reducing costs below those of competitors, should prove financially rewarding well into the future.