DUCKWEED AQUACULTURE AND AQUASANITATION

Introduction The botanical family *Lemnaceae*, the common duckweeds, are small floating vascular plants found worldwide on still, nutrient-rich fresh and brackish waters. About 40 species have been identified so far among four genera. Duckweed species grow most rapidly on still waters with high concentrations of fermenting organic material, i.e. a swamp-like environment. Farm-scale research demonstrates that duckweed species have great potential as a new crop because of high production rates, the high nutritional value of their biomass, the relative ease of harvesting them, and their growth habit on eutrophic water bodies.

Duckweed species have no leaf, stem or specialized structures; the entire plant consists of a *frond* which may have hairlike roots. Virtually all of the tissue of duckweed is metabolically active and very low in fiber. Nutrients are absorbed through all surfaces, and duckweed's photosynthetic efficiency (about 4.5 percent) is higher than most plants. Reproduction of duckweed species is primarily vegetative, resembling exponential microbial growth more than that of terrestrial plants. Duckweed species may be cultivated continuously in semi-tropical and tropical climates, yielding 30 to 40 metric tons/hectare/year (ton/ha/year) of solid material.

Fresh duckweed contains 92 - 94 percent water, but the solid fraction of cultured duckweed is high in protein (30 - 45 percent) and high in essential amino acids, particularly lysine. Its amino acid profile is comparable to soy protein, and it is high in trace minerals and pigments, particularly beta carotene. Duckweed colonies float freely on the surface of ponds and may be skimmed with a floating mechanized harvester or with hand-held dip nets. Fresh duckweed can be fed directly to certain fish without processing, and the excess can be sun-dried for blending with other ingredients as animal feed rations. The dried, whole meal can be pelletized in standard equipment without the need to add a binding agent.

Fish Feed Tilapia and a polyculture of carp species were fed fresh duckweed in a demonstration project in Bangladesh. Using fresh, green duckweed as fish food eliminates processing costs. The nutritional requirements of carp and tilapia are met in ponds receiving only fresh duckweed, despite the relatively dilute concentration of nutrients in fresh plants. Yields from duckweed-fed fish farming in Bangladesh ranged from 10 to 14 metric ton/ha/year.

Poultry Feed Feeding trials in Peru demonstrate that duckweed meal can be substituted for soybean and fish meal as the protein component in prepared rations for several types of poultry, including broilers, layers, and chicks. Acceptable levels of duckweed meal in the diets of layers range up to 40 percent of the total weight of the feed. Duckweed-fed layers produce the same amount of eggs of the same or higher quality as control birds fed the recommended formulated diets. Levels of up to 15 percent duckweed meal produce growth rates in broilers equal to those fed control feeds. Diets for chicks containing up to 15 percent duckweed meal are suitable for birds under three weeks of age.

Integrated Farming Systems Highly productive aquatic farming systems have been demonstrated in Bangladesh: (a) a resource recovery system using domestic wastewater as the growth medium for duckweed cultivation and (b) hydroponic farming systems using macronutrients from commercial fertilizers and micronutrients from unrefined sea salt. Duckweed cropping systems may also include terrestrial plants and emergent aquatic plants

as collateral crops to increase overall cropping intensity. Co-crops benefit from the abundant water while buffering against wind and high temperatures. The value of co-crops depends on local demand and the relative importance of wind and temperature buffering at the farm site.

Wastewater Treatment Duckweed species bioaccumulate as much as 99 percent of the nutrients contained in wastewater and produce valuable, protein-rich biomass as a byproduct. Cultivation of duckweed on wastewater is a special case of duckweed aquaculture known as "aquasanitation". An aquasanitation system consists of a series of lagoons modified to support optimal duckweed growth and harvesting and fish culture in separate ponds. Aquasanitation differs from conventional wastewater treatment processes in its simplicity, high efficiency, and generation of revenues from its several products, including fish, duckweed meal, and a high quality treated effluent sufficiently free of nutrients and dissolved solids to be recyclable.

Aquasanitation systems are more effective than waste stabilization lagoons because they actively suppress algae and remove nutrients from the wastewater stream. Algae account for most suspended solids in lagoon effluents. The aquasanitation treated effluent typically contains less nitrogen, phosphorus, and algae than the receiving streams into which it is discharged. The treated effluent contains relatively few organic compounds and human enteric pathogens. A pilot wastewater treatment plant in Mirzapur, Bangladesh, has been in operation since July 1990, treating an average of 120 m^3/day of wastewater from a population of 3,000. The final treated effluent from the 0.5 hectare plant exceeds the highest quality standards mandated by the Environmental Protection Agency in the USA, as shown below in Table 1.

Table 1. Effluent quality for March 23, 1991 at Bangladesh Demonstration

Treatment Phase	BOD_5 (mg/l)	NH3/NH4 (mg/l)	P (mg/l)	S. Solids (mg/l)
Raw influent	120	39.4	1.9	57
Primary	60	32.2	2.0	43
Final	1	0.03	0.03	5

An aquasanitation system is also a duckweed farm. The rapidly growing plants assimilate nutrients from the wastewater -- N, P, Ca, Na, K, C and Cl ions, among others. Harvesting creates a **nutrient sink**, and the nutrients are permanently removed from the system. Toward the end of the treatment process, depletion of nutrients slows duckweed growth. The starved plants begin to mineralize heavily as they process water in search of growth nutrients, and they absorb virtually everything dissolved in the wastewater stream. A one hectare wastewater treatment plant in Bangladesh will typically average about one ton/ha/day of fresh plants. This daily harvest converts to approximately 100 kg of fish, or after drying, yields about 80-100 kg of high-protein duckweed meal. At a yield rate of 10 tons/ha/year, net revenues from duckweed-fed carp farming in Bangladesh average over $16,000/ha/year.