Common Name	Palmer's trumpet
Height	40-60 feet
Growth Rate	Fast
Hardiness	24 dF, more drought tolerant than Ipe roseo
Plant Type	Deciduous from December to March
Foliage Char.	Green palmate leaf
Flower Color	Magenta to wine red with bright yellow corolla
Flower Char.	2-2.5" trumpet flowers usually in clusters
Flwr. Season	Late Novemberr to December
Nutrition	Wide range
Uses	Accent, park, residence, perimeter plantings, golf courses
Sources	USDA Miami, Palm Beach County park system
Germination	Seed matures in February, germination is difficult in winter
Importance	#5, This tree has great potential for use as a winter bloomer and in energy landscaping for winter sun and summer shade

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CHINESE WATERCHESTNUTS IN FLORIDA—PAST, PRESENT, AND FUTURE[1]

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Abstract. **The Chinese waterchestnut (*Eleocharis dulcis* (Burm. f.) Trin. ex Henschel), is represented by two forms, the wild, with small, hard corms which abounds in fresh, brackish and saline waters of southern Asia and much of Oceania (eaten directly and made into starch), and the cultivated, large, sweeter, juicier corm developed in China and widely cultivated commercially. The improved cultivar was introduced into the United States in 1934 and grown mainly for research purposes at the USDA Barbour Lathrop Plant Introduction Garden, Savannah, Georgia; commercially by James Banks at Orlando, Florida; for education and distribution by Professor G. W. Groff at Laurel, Florida; and, since 1960, for research and development, at the Richard B. Russell Agricultural Research Center, Athens, Georgia. In recent years, the demand for waterchestnuts has increased in the United States. As part of a program exploring the prospects of growing aquatic vegetables in areas of the Everglades subject to critical soil subsidence, the University of Florida's Everglades Research and Education Center at Belle Glade began tank culture of waterchestnut in 1975. Results have been favorable and field trials are under way with a view to assisting expansion of waterchestnut production in Florida. Cultural and nutritional studies are being conducted as well as salinity tests, and investigations of the potential utility of the waterchestnut for waste water treatment.**

The Chinese waterchestnut *Eleocharis dulcis* (Burm. f.) Trin. ex Henschel (syns. *E. tuberosa* Schult.; *Scirpus tuberosus* Roxb.; *Heleocharis plantaginea* R. Br.; *Andropogon dulce* Burm. f.), is so-called to distinguish it from the aggressively weedy *Trapa natans* L. (family Trapaceae) which has been widely known as waterchestnut for a longer time. Other names for *Eleocharis dulcis* include waternut, matai (in China), *ma thay* (in Vietnam), *apulid* (in the Philippines), *chikai*, *dekeng* or *tekee* (in Indonesia) and a number of dialectal appellations. The United States Department of Agriculture at one time proposed that the name waternut be chosen for *Eleocharis dulcis* but it was viewed as not being sufficiently different from waterchestnut. The Chinese matai was then suggested, but not generally adopted (26).

Description

The Chinese waterchestnut is the 4- to 6-ringed, oblate, crisp, white-fleshed, juicy, sweetish, starchy corm (2.5 to 5 cm wide) developing, at a depth of 15 to 25 cm, at the tips of slender, late-appearing rhizomes radiating and descending from the base of a dense tuft of slim, tubular, green, ringed leaves to 2 m high, which are hollow except for membranous partitions spaced at intervals (Fig. 1, 2, and 3)). The leaves are usually pale at the base with dry, brown sheaths. In the wild form, 'Sui matai', (cultivated only in China and perhaps Japan), the leaves are 1 to 10 mm broad and the corm small, black-skinned and relatively hard and dry. Minute flowers are massed in spikes 2 to 3 cm long at the tips of the leaves. The plant spreads by early, horizontal rhizomes which do not bear corms (2, 5, 13, 21).

Origin and Distribution

This sedge is native to eastern Asia and of ancient cultivation in ponds or tanks (25) in eastern and southeastern China, Taiwan and Hong Kong, and throughout former Indo-China. Quantities have long been exported to Calcutta and Singapore (6). The plant grows wild especially in the Yangtze valley of China (25); also in Indonesia in fresh-

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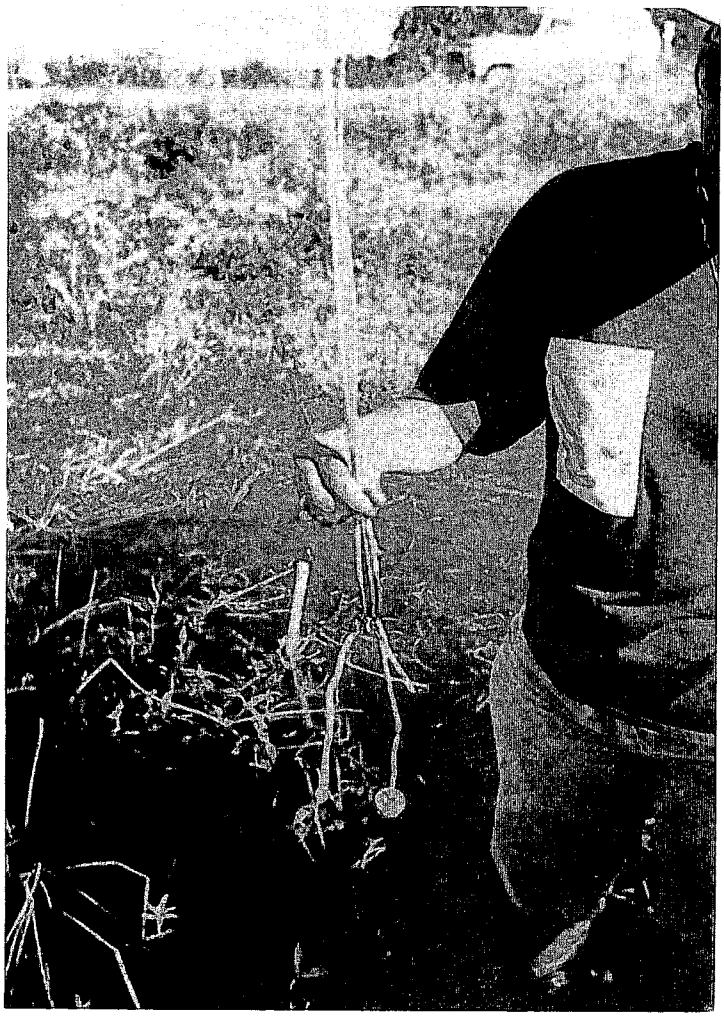

Fig. 1. Chinese waterchestnuts (*Eleocharis dulcis*) tubular leaves, rhizomes, and immature corm. (Photo by G. H. Snyder)

water, brackish, and saline swamps and in rice fields, usually below 50 m elevation, but occasionally up to 1,000 m. Corms collected from coastal marshes of Djakarta, Indonesia are commonly marketed. There are extensive wild stands bordering streams and swamps in Australia (8). The

Fig. 2. Harvesting Chinese waterchestnuts from muck soil. Note mass of large developed corms. (Photo by G. H. Snyder)

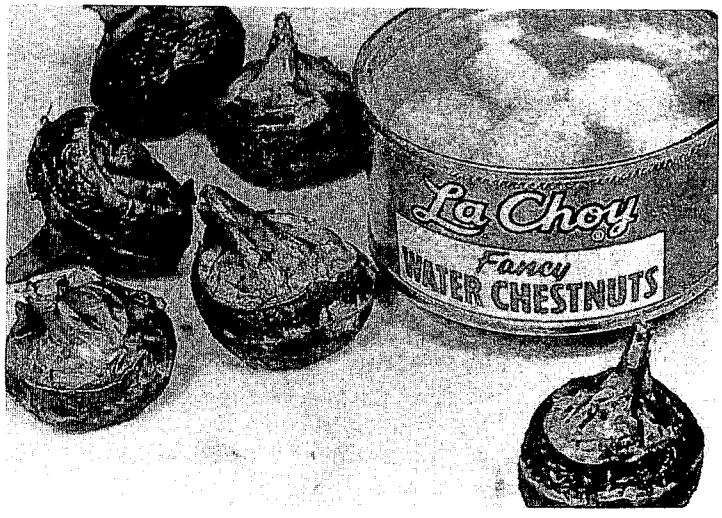

Fig. 3. Fresh and canned corms of chinese waterchestnut. (Photo by J. F. Morton)

plant is commonly grown in tropical, subtropical and warm-temperate wetlands of Madagascar, central Africa, India, Malaysia and the Pacific islands (18). In Samoa, it grows in tidal swamps and in shallow fresh water up to 700 m elevation (7). In many parts of India, wild stands occur in shallow lakes and swamps up to 1000 m (1). The cultivated form became known to Europeans in the 17th Century.

Fresh corms, unpeeled, were imported into the United States by Chinese food dealers for many years, before the coming of the peeled, canned product. About 1930, there arose serious interest in cultivating the crop in the southern United States. Corms of a superior strain, 'Hon matai', were requested from Lingnan University in Canton and a shipment was received by the U. S. Department of Agriculture in 1934. These were planted at the Barbour Lathrop Plant Introduction Garden at Savannah, Georgia. Corms produced there were distributed in small lots to experimenters throughout the United States (as far north as Virginia) but with little result except for a commercial plantation established by James Banks at Orlando, Florida.

In 1942, a test planting was made at Laurel, Florida, by Professor G. Weidman Groff, formerly at Lingnan University. He supplied corms to potential growers each year from fall to early spring (10) for the rest of his life. The cessation of imports from China in 1950, because of a trade embargo, stimulated efforts to encourage domestic production, and the U. S. Department of Agriculture issued Circular 956, *The Chinese Waterchestnut*, in 1955 (14).

In 1972, China's best strain was introduced into the Philippines where it is called '*apulid sungsuno*'. After two years of experimental work in Mindanao, it was declared to be well adapted to local conditions and a planting of 182 square m was established at the Mindanao Rice and Corn Experiment Station (9). In December 1987, large-scale waterchestnut cultivation was launched in Hawaii.

Despite commercial culture in the Coachella Valley, California, in 1966 and earlier (20), we located only one current small paddy in that state. The grower maintained the crop from 1982 to 1986, did not use herbicide, and discontinued production for 2 yr because of weeds. He resumed production for local sale, by raising water levels to discourage weeds (F. Maurer, personal communication).

Chinese and Japanese residents of Florida have long grown the plant in limited amounts for home use and for local marketing. Some non-Oriental private growers have been raising small crops and selling the corms to others for planting. As part of a program exploring the prospects of growing aquatic vegetables in areas of the Everglades subject to critical soil subsidence, the University of Florida's Everglades Research and Education Center began tank culture in 1975 (19). Plantings were made from a seed stock of PI 106274 provided by Dr. Miller of the U. S. Plant Introduction Center in Savannah, Georgia. Initial plantings were made to assess the adaptability of the crop to the climate and soil conditions of the Everglades. More recently, studies were initiated to evaluate the salt tolerance and potential utility of Chinese waterchestnuts for waste water treatment.

In 1988 six additional plant introductions of Chinese waterchestnts were obtained from J. D. Brown, a small producer near Pensacola. This same year field studies were initiated to identify suitable cultural and nutritional practices for the production of Chinese waterchestnuts under Everglades conditions.

Soil and Culture

The waterchestnut does not grow well in acid or very sandy soil (10). Muck or rich clay soils with natural or adjusted pH of 6.9-7.3 are the basis of Chinese waterchestnut culture in the Orient (14), though these soils "cake" when dry and the chunks must be broken apart during harvesting to recover the corms (13, 28). Experimenters at Athens, Georgia, strongly favor sandy loam for easier harvesting. Land must be well prepared and leveled, then dikes must be constructed to provide a controlled water supply. A "hardpan" understructure helps conserve water and nutrients (28). Fertilizer, at the rate of 2.5 MT/ha, complete in P and K, should be applied 1/3 to 1/2 before planting, 1/2 of the remainder 2 months after planting, and the rest before the corms develop (14).

Chinese farmers keep their seed corms coated with mud to prevent dehydration and rotting, and store them over winter in outdoor pits (28). Otherwise they should be refrigerated at 10 to 13°C (16).

They must be planted before drying out and before they have gone beyond the first sign of sprouting (26). They can be started indoors or outside in seedbeds; in moist soil 10 cm deep and well-watered. Plantings can be established either from corms or transplants set in the field (27). Propagation by transplants generally results in maturity 6 weeks earlier than that from corms (29). Commercial propagations from seed is not feasible because seeds are slow to germinate, show a poor percentage germination, and require two years from planting to development of normal size corms. In the Philippines (9) and other warm climates, planting can be done at any season. The crop needs a minimum of 220 frost-free days. At Savannah, Georgia, planting in the field is done in mid-May when the leaves are 25 to 30 cm high. In southern Florida plantings can be in early March but good yields can be obtained with plantings as late as June.

The corms are placed 75 cm apart in rows 90 cm apart, and covered with 5 to 10 cm of soil. Sowing a one-hectare field requires 500 kg corms. The field must be immediately flooded with at least 12.5 cm of water which is allowed to drain off. Within a week after planting, the field is reflooded with 10 to 20 cm of water. This level should be maintained throughout most of the growing season (14). Lack of water for extended periods may result in crop failure (9).

By August or September, the rhizomes will have spread to form a dense stand, filling the rows. Chinese waterchestnut fields need little or no weeding if the ground has been well cleared and pretreated with herbicide.

Flowering and subsequent corm development will take place in early fall. By late November, the tops turn brown. The field is then drained and the dry tops may be burned so they will not harbor rodents that ravage the corms. Harvesting is begun 2 or 3 weeks later, though it can be delayed for up to three months, if desired, as the corms keep well underground unless a severe frost occurs (14). If the ground temperature rises above 13°C the corms will sprout; and, in temperate climates, should be harvested and refrigerated until the next planting season (13). In warm climates they can be left to continue developing as a perennial crop (10).

Home gardeners wishing to grow Chinese waterchestnuts can do so in any water-tight container. Small inexpensive plastic childrens' swimming pools serve the purpose well (23). A home grower might realize up to 9 kg of corms per square meter of planted area. On a retail basis this amounts to more than $40. Furthermore, because the crop stores well underground a home grower can utilize the waterchestnuts over an extended period of time without processing or preserving the crop.

Harvesting

The corms may be manually harvested with a trowel, or a small plow or harrow may be used to turn the soil to a depth of 15 cm, the corms are then uncovered with a rubber-covered rake and picked up by hand (17). At Savannah, the soil was carefully lifted and spread over wire-mesh frames with 2-cm apertures. Rubber paddles were used to agitate and sift the soil and the exposed corms were dropped into buckets of water to avoid bruising and to begin the cleaning process (14).

A mechanical harvester was under development at the Richard B. Russell Agricultural Research Center at Athens, Georgia, in 1976. Government support declined with the resumption of trade with China, but one of the staff, and two associates continued to improve the machine on their own and demonstrated its practicality in their field at Sandy Point. They hope to semi-mechanize the post-harvest handling as well. By 1982, they were adding to their land-holdings. They sort the corms by flotation. Those that sink are sold for cattlefeed. The floaters are shipped unpeeled by air to Frieda's Finest Product Specialties in Los Angeles, whence, repackaged, they are distributed to retail markets around the country (27).

Yield

A single plant of the superior Chinese strain yields 2.3 kg per season. This indicates that a grower could realize 92,000 kg/ha (9). Yields in Georgia average about 48,000 kg/ha. Yields on histosols in southern Florida range from 47,000 kg/ha to 85,000 kg/ha (Table 1). It now seems that expansion of Chinese waterchestnut production could be

Table 1. Yield and distribution of sizes of waterchestnuts obtained under Everglades conditions.

		Size					
		<2 cm	2-3 cm	3-4 cm	4-5 cm	>5 cm	Total
Yield	(Kg ha^{-1})	37	14,053	34,621	30,275	218	82,906
Size distribution	(%)	4.5	17.0	41.8	36.5	0.25	

Total lipid (fat)
Total lipid (fat)
Ascorbic acid

profitable. One fast-food chain alone was recently seeking an annual supply of approximately one million kg. Currently, about 100,000 kg. of freshwater chestnuts, unpeeled and still coated with their preservative mud, are imported into the United States annually from China and Taiwan (27). There is still an unfilled demand despite imports also from Mexico (20).

Pests and Diseases

In the Philippines, the main pests of Chinese waterchestnut are the green and long-horned grasshoppers but these are controlled by insecticides (9). Professor Groff reported that the only pest troubling his crop at Laurel was a rice water weevil (*Lissorhoptrus ozyzophilus*) which tunneled into the corms, and that heavy infestations occurred in the Banks field at Orlando, but that they were successfully combatted with pesticides (10). Water weevils are easily controlled in rice by removing the flood for a period of about one week (3), which waterchestnuts would tolerate after crop establishment. A billbug (*Calendra cariosa*) which feeds on native sedges, damaged a test planting in central Florida (14).

The primary disease is rust caused by *Uromyces* sp. which appears in about 5 months from planting as brown dots, later yellowish, and then orange-brown if untreated. Early applications of sulfur dust prevented its development (9). A stem fungus (*Cylindrosporium* sp.) has attacked plants on highly acid soil—pH 5.5 (14). Nevertheless, over the past 13 years in which we have produced waterchestnuts in the Everglades we have had no serious insect or disease infections and have produced successful crops without the use of insecticides or fungicides.

Storage

Clean, undamaged, air-dried corms, in moisture-proof but not air-tight containers, remain in good condition for 6 months at temperatures ranging from 1.1 to 4.4°C (14). In climates with moderate winter temperatures, corms can be left under ground and harvested as needed. Work is currently being coordinated by Dr. Brecht of the University of Florida to assess the effect of harvest date and storage conditions on the postharvest quality of Chinese waterchestnuts.

Peeling

A handicap to commercial production of Chinese waterchestnuts in the U.S. is the difficulty in peeling. Where laborers are available at low wages, corm peeling is done by hand. It is best accomplished by first slicing off the top and the bottom, and then the circumference. The shape of the corm is not well adapted to mechanical methods. An experimental peeler used at the Northern Regional Research Laboratory yielded only 6 peeled corms per minute (20). Chemical methods have been investigated also. Nevertheless, major advances in peeling technology are needed.

Food Uses

The wild Chinese waterohestnut is believed to be the aquatic tuber eaten by the Australian aborigines, raw or baked, or ground into flour (8). Such a flour, called *ma tai fan* (12) is marketed in northern China (6). Hodge (13) describes its preparation; the washed tubers are first grated against ridges inside earthenware bowls. The grated material is put into a bamboo basket beneath which is a cloth filter and a pot suspended over a wood fire. After adding water and stirring for 15 min, the worker pours off a milky fluid and proceeds with the settling and decanting process and the starch is finally sun-dried.

In southern China, several peeled fresh corms are skewered on a bamboo stick from which they are munched (15). Peeled and sliced or shredded, waterchestnuts are traditionally added to soups, to meat and rice preparations, omelettes, puddings, and a kind of cake or sweetmeat (13). Sliced Chinese waterchestnuts are standard ingredients in American chop suey and chow mein. In Hawaii, a dish called *chun fa kuen* ("Spring Flower Roll") is made of fish cake, chopped shrimp, ham, Chinese waterchestnuts, peanuts and green onion. The mixture is rolled in fat, steamed, fried and topped with sweetened soy sauce (4).

In Djakarta, the wild corms, gathered by wading, are cooked, dehusked with a hammer, then pounded to a meal that is dried and fried in coconut oil (21). In the Philippines, the wild corms (1 to 1.5 cm wide), unpeeled or peeled, are boiled and eaten. The more delicate and sweeter imported corms (2.5 to 4 cm wide) are sliced and cooked for 15 min in slightly salted water, cut up and added to various Oriental dishes (9). Undersized corms can be pickled (13).

Preservation

Chinese waterchestnuts can be home-canned in glass jars after processing in a pressure cooker at 115.6°C—30 min for pint jars and 40 min for quarts. Commercially the corms are first treated at 50°C and then processed at 115.6°C for 30 to 45 min depending on size of can. Some of the flavor is lost but the crisp texture is unaffected (14).

In freezing tests at the Western Regional Research Laboratory of the U. S. Department of Agriculture, it was found that peeled, blanched waterchestnuts maintained at −17.8°C had better flavor and color than the unblanched (20).

Food Value

It appears that the fresh Chinese waterchestnuts have a greater food value than the canned product (11) (Table 2). For example, fresh corms contained 59% more protein than canned, double the carbohydrate, and three times the potassium of the canned product. Based on limited data, wild and cultivated corms have similar food value (5) (Table 3).

Table 2. A comparison of food value of peeled fresh and canned Chinese waterchestnuts.[z]

Fresh					Canned				
		Amount in 100 grams, edible portion					Amount in 100 grams, edible portion		
Nutrients and units		Mean	Standard error	Number of samples	Nutrients and units		Mean	Standard error	Number of samples
PROXIMATE:					PPROXIMATE:				
Water	g	73.46	4.324	3	Water	g	86.42		
Food energy	kcal	106			Food energy	kcal	50		
	kj	443				kj	211		
Protein (N x 6.25)	g	1.40		1	Protein (N x 6.25)	g	0.88	0.037	6
Total lipid (fat)	g	1.40		1	Total lipid (fat)	g	0.06		1
Carbohydrate, total	g	23.94			Carbohydrate, total	g	12.43		
Fiber	g	0.80			Fiber	g	0.58		1
Ash	g	1.10			Ash	g	0.34		1
MINERALS:					MINERALS:				
Calcium	mg	11		1	Calcium	mg	4	0.433	6
Iron	mg	0.60		1	Iron	mg	0.87	0.022	6
Magnesium	mg	22	10.100	2	Magnesium	mg	5		1
Phosphorus	mg	63		1	Phosphorus	mg	19		1
Potassium	mg	584	83.550	2	Potassium	mg	118	0.241	6
Sodium	mg	14	5.700	2	Sodium	mg	8	1.260	4
Zinc	mg				Zinc	mg	0.38		1
Copper	mg				Copper	mg	0.100		1
Manganese	mg				Manganese	mg			
VITAMINS:					VITAMINS:				
Ascorbic acid	mg	4.0		1	Ascorbic acid	mg	1.3	0.065	6
Thiamin	mg	0.140		1	Thiamin	mg	0.011	0.006	6
Riboflavin	mg	0.200		1	Riboflavin	mg	0.024	0.011	6
Niacin	mg	1.000		1	Niacin	mg	0.360	0.024	6
Pantothenic acid	mg				Pantothenic acid	mg			
Vitamin B_6	mg				Vitamin B_6	mg			
Folacin	mcg				Folacin	mcg			
Vitamin B12	mcg	0			Vitamin B_{12}	mcg	0		
Vitamin A	RE			1	Vitamin A	RE	0	0.080	6
	IU	0		1		IU	4	0.804	6

[z]Adapted from Haytowitz and Matthews (11).

Medicinal Uses

The corms contain an antibiotic substance, *puchiine*, that is a potent inhibitor of the growth of *Staphyloccus* and *Escherichia coli* (22). In China, waterchestnuts are given as an antidote to poisons. The extracted, large-grained starch is believed to be soothing in the digestive tract and is administered to children who have swallowed coins or other metal objects (24).

Table 3. Comparative analyses of wild and cultivated Chinese waterchestnuts.[z]

	Wild	Cultivated
Moisture (%)	41.81	79.9
Ash (%)	1.10	1.17
Phosphorus (%)	0.34	0.21
Calcium (%)	0.02	0.005
Iron (%)	0.003	0.006
Protein (%)	2.68	1.30[y]
Fat (%)	1.62	0.20[y]
Carbohydrates (%)	45.82	—
Crude Fiber (%)	1.06	0.60[y]

[z]Adapted from Brown (5).
[y]Values taken from the cultivated sungsung at the Philippine Food and Nutrition Center.

By-Products

Dry leaves, if they can be economically harvested, have uses as cattlefeed, mulch or compost, and as packing material (16). They are sometimes used for making mats but these are not durable (6).

The Future of Chinese Waterchestnuts in Florida

Chinese waterchestnuts were first introduced into Florida over 50 years ago, however, there has been little progress toward the establishment of a viable industry. This may be due to the lack of a suitable mechanical harvester and the high labor cost that would be involved in hand harvesting and peeling the crop. An experimental mechanical harvester is being tested in Georgia and if proven successful this may encourage the development of a waterchestnut industry in Florida.

Perhaps another factor limiting the development of the industry in southern Florida is the lack of information concerning suitable cultural and nutritional practices under Florida conditions. Research is currently being conducted at the Everglades Research and Educations Center to address this need. Research is also being conducted by University of Florida researchers in several Caribbean nations where labor on small family farms can be supplied as part of the family unit. Furthermore, the development of a suc-

cessful industry in the Caribbean basin would strengthen a Florida based marketing infrastructure by providing a supply of this commodity when it is not available in Florida.

Because Chinese waterchestnuts are well adapted to the subtropical climate in south Florida, because they produce large yields with a limited resource input, because there is an already present and growing U. S. market, and because they would be an ideal crop from an environmental standpoint for natural wetlands such as the Everglades Agricultural Area, prospects for a thriving industry in Florida remain good. In addition, Chinese waterchestnuts would be an ideal crop for backyard gardeners in Florida who relish oriental cuisine and the crisp texture of the corms.

Acknowledgement

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