Promoting the conservation and use of underutilized and neglected crops. 8.

Chayote

Sechium edule (Jacq.) Sw.

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Foreword

Humanity relies on a diverse range of cultivated species; at least 6000 such species are used for a variety of purposes. It is often stated that only a few staple crops produce the majority of the food supply. This might be correct but the important contribution of many minor species should not be underestimated. Agricultural research has traditionally focused on these staples, while relatively little attention has been given to minor (or underutilized or neglected) crops, particularly by scientists in developed countries. Such crops have, therefore, generally failed to attract significant research funding. Unlike most staples, many of these neglected species are adapted to various marginal growing conditions such as those of the Andean and Himalayan highlands, arid areas, salt-affected soils, etc. Furthermore, many crops considered neglected at a global level are staples at a national or regional level (e.g. tef, fonio, Andean roots and tubers etc.), contribute considerably to food supply in certain periods (e.g. indigenous fruit trees) or are important for a nutritionally well-balanced diet (e.g. indigenous vegetables). The limited information available on many important and frequently basic aspects of neglected and underutilized crops hinders their development and their sustainable conservation. One major factor hampering this development is that the information available on germplasm is scattered and not readily accessible, i.e. only found in 'grey literature' or written in little-known languages. Moreover, existing knowledge on the genetic potential of neglected crops is limited. This has resulted, frequently, in uncoordinated research efforts for most neglected crops, as well as in inefficient approaches to the conservation of these genetic resources.

This series of monographs intends to draw attention to a number of species which have been neglected in a varying degree by researchers or have been underutilized economically. It is hoped that the information compiled will contribute to: (1) identifying constraints in and possible solutions to the use of the crops, (2) identifying possible untapped genetic diversity for breeding and crop improvement programmes and (3) detecting existing gaps in available conservation and use approaches. This series intends to contribute to improvement of the potential value of these crops through increased use of the available genetic diversity. In addition, it is hoped that the monographs in the series will form a valuable reference source for all those scientists involved in conservation, research, improvement and promotion of these crops.

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Rafael Lira Saade
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1 Introduction

Chayote is the Nahuatl name used in many parts of Latin America for the cultivated species *Sechium edule* (Jacq.) Swartz. Its variable fruits, as well as its roots, have been important elements in the diet of the people living in these and other areas of the world. However, as is the case with many other crops, in spite of the fact that chayote is widespread and is an important export crop for some Latin American countries, much still needs to be learned about it. More information is needed on the biological characteristics of this crop, on how to improve it, and how it is related to wild species of the genus, as well as how to conserve its genetic resources.

2 Taxonomy and names of the species

2.1 History and taxonomy of *Sechium edule*

The most recent classification of the Cucurbitaceae (Jeffrey 1990) places the genus *Sechium*, to which chayote belongs, in the subtribe Sicyinae of the tribe Sicyeae, along with the genera *Microsechium*, *Parasicyos*, *Sechiopsis*, *Sicyosperma* and *Sicyos*. The members of this subtribe are characterized by having spiny pollen, a single pendulous ovule and single-seeded fruits. When the first monograph on the Cucurbitaceae was published (Cogniaux 1881), *Sechium* was considered monospecific and only to contain *S. edule*. This species was originally discovered by Browne (1756) in Jamaica, and in 1763 it was classified simultaneously as *Sicyos edulis* by Jacquin and as *Chocho edulis* by Adanson.

Later, Jacquin (1788) changed it to *C. edulis* and placed it in his genus *Chayota*. A few years later, Swartz (1800) became the first to include this species in *Sechium*, when he proposed the combination by which it is still known, *S. edule* (Jacq.) Swartz. During the last century, another three species were described as belonging to *Sechium*. These did not always correspond to the taxonomic limits of this genus, however, and they are now placed in the synonymy of other genera, or in that of *Sechium* itself.

Almost a century after the publication of Cogniaux's monograph, Jeffrey (1978) widened the taxonomic limits of *Sechium* by including several Mexican and Central American taxa which other authors had described in, or later transferred to, genera such as *Cyclanthera, Ahzolia, Frantzia, Microsechium* and *Polakowskia* (Cogniaux 1891; Donnell-Smith 1903; Pittier 1910; Standley and Steyermark 1944; Wilson 1958; Wunderlin 1976). All of these taxa share the presence of nectaries at the base of the flower receptacle of both sexes, a complex and variable androecium structure, and produce medium to large fleshy-fibrous fruit.

According to this new generic circumscription, *Sechium* included seven species arranged in two sections, *Sechium* and *Frantzia*, which differ in the morphology of the floral nectaries and the arrangement of the stamens. Thus, *Sechium* included species with naked floral nectaries visible from above, partially or totally joined filaments and free anthers. This section included *S. edule* (Jacq.) Swartz, *S. hintonii* (P.G. Wilson) C. Jeffrey, and *S. compositum* (J. D. Smith) C. Jeffrey, as well as *S. tacaco* (Pittier) C. Jeffrey and *S. talamancense* (Wunderlin) C. Jeffrey. *Frantzia*, on the other hand, was originally proposed by Wunderlin (1976), for the genus of the same name, and placed in the *Sechium* synonymy by Jeffrey (1978). It included two species: *S. pittieri* (Cogn.) C. Jeffrey and *S. villosum* (Wunderlin) C. Jeffrey, whose floral nectaries are covered by a cushion- or umbrella-shaped spongy structure, whose filaments merge to form a column and whose anthers merge together to form a globose structure.

A year before the publication of Jeffrey's work, Wunderlin (1977) described an additional *Frantzia* species from Panama (*F. panamensis* Wunderlin), which he placed in the typical section of this genus. Soon afterwards, L.D. Gómez (Gómez and

Gómez 1983), ignoring Jeffrey's (1978) generic proposal, described a new species from Costa Rica under the genus *Frantzia*, using the binominal *Frantzia venosa* L.D. Gómez. Apparently he failed to notice that the floral nectaries of his new species were covered with the pillow-, cushion- or umbrella-shaped spongy structure which characterizes species in Wunderlin's (1976) *Frantzia* section, and he wrongly placed it in the section *Polakowskia sensu* Wunderlin (1976). Since neither of these two species was reclassified in *Sechium*, either by C. Jeffrey or by any other author in the 1980s, the generic limits of this genus became vague once again.

Although Jeffrey's proposed taxonomic broadening of *Sechium* (1978) was not widely acclaimed, there is little doubt that his work awakened new interest in the genus. As a result of Jeffrey's proposal, the relatives of *Sechium edule* were described formally for the first time in the literature, although other authors had already suggested the closeness of many of them to this species (see Standley and Steyermark 1944 for *Ahzolia composita=Sechium compositum*). And the widening of the limits of the genus, to include another cultivated species, *S. tacaco* (Pittier) C. Jeffrey, helped underline the importance of studying *Sechium*, not only from a strictly taxonomic point of view, but also in the general context of plant genetic resources conservation and use.

Mainly as a result of the above, there was an increase in botanical exploration, aimed at finding a more representative range of species in the genus, as well as variations of its cultivated species. At the beginning of the 1980s, for example, three wild *Sechium* populations were discovered in the State of Veracruz (Cruz-León 1985-86). This was undoubtedly a major step forward in the search for knowledge about the relationship between wild and cultivated species in the genus. After several years' study of these populations, they were defined as 'wild' types of *Sechium edule* (Jacq.) Swartz, but were not placed in any specific taxonomic category (Cruz-León 1985-86; Cruz-León and Querol 1985).

During the same period, Newstrom (1985, 1986) reported finding several populations in Oaxaca that were similar to those of Veracruz, and began a series of studies,aimed at defining the origin and evolution of *Sechium edule*. In order to do this, she also studied the populations of some of the species transferred by Jeffrey (1978) to the *Sechium* genus, as well as those of a wild species from the State of Veracruz, recently recognized by Nee (1993) simply as *Frantzia* sp.

Newstrom's work also included a new taxonomic delimitation of *Sechium*, in which the genus would be reduced to only three species: *S. edule* (Jacq.) Swartz (represented by wild and cultivated types), *S. compositum* (J.D. Smith), C. Jeffrey and *S. hintonii* (P.G. Wilson) C. Jeffrey. Accordingly, *Frantzia* and *Polakowskia* would be reinstated as independent genera, thereby also discarding the proposal made years before by Wunderlin (1976) to join them together. In a later work, however, Newstrom (1990) suggested that *Sechium, Polakowskia* and *Frantzia* could be considered as sections of *Sechium*, although, as with the above case, she never formally made such a proposal. Table 1 compares Jeffrey's (1978) and Newstrom's (1986) taxonomic classification proposals for *Sechium*.

Table 1. Proposed taxonomic classifications of *Sechium* and related genera

Jeffrey (1978) *Sechium sensu lato*	Newstrom (1986) *Sechium sensu stricto*
Section *Sechium*	**No sections**
S. compositum (J.D. Smith) C. Jeffrey	*S. compositum* (J.D. Smith) C. Jeffrey
S. edule (Jacq.) Swartz	*S. edule* (Jacq.) Swartz (wild and cultivated)
S. hintonii (P.G. Wilson) C. Jeffrey	*S. hintonii* (P.G. Wilson) C. Jeffrey
S. tacaco (Pittier) C. Jeffrey	
S. talamancense (Wunderlin) C. Jeffrey	***Polakowskia sensu lato***
	P. tacaco Pittier
Section *Frantzia*	*P. talamancense* (Wunderlin) Newstrom
S. pittieri (Cogn.) C. Jeffrey	
S. villosum (Wunderlin) C. Jeffrey	***Frantzia sensu stricto***
	F. pittieri (Cogn.) Pittier
	F. panamense Wunderlin
	F. venosa L.D. Gómez
	F. villosa Wunderlin

Table 2. Taxonomic classification of the genus *Sechium* P.Br. adopted in this book

Section *Sechium*	Section *Frantzia*
S. compositum (J.D. Smith) C. Jeffrey	*S. panamense* (Wunderlin) Lira & Chiang
S. chinantlense Lira & Chiang	*S. pittieri* (Cogn.) C. Jeffrey
S. edule (Jacq.) Swartz (wild and cultivated)	*S. venosum* (L.D. Gómez) Lira & Chiang
S. hintonii (P.G. Wilson) C. Jeffrey	*S. villosum* (Wunderlin) C. Jeffrey
S. tacaco (Pittier) C. Jeffrey	*Sechium* sp.
S. talamancense (Wunderlin) C. Jeffrey	

During the 1990s, the disagreement among botanists about the taxonomic limits of *Sechium* gave rise to a series of studies aimed at clarifying the problem (Lira and Soto 1991; Alvarado *et al.* 1992; Lira and Chiang 1992; Mercado *et al.* 1993; Lira *et al.* 1994; Mercado and Lira 1994; Lira 1995a, 1995b). The results of these studies have shown that *Sechium* is a well-defined genus composed of 11 species (Table 2). Of these, nine are wild species distributed throughout central and southern Mexico, up to Panama (Figs. 1 and 2). Of the two remaining species, *S. tacaco* is only cultivated in Costa Rica, and the other, *S. edule*, as mentioned above, is widely cultivated throughout the Americas and other regions of the world, with wild populations in southern Mexico.

2.2 Scientific name and synonymy

The correct scientific name for chayote is *Sechium edule* (Jacq.) Swartz, which, as discussed above, was formally published in 1800, and is based on *Sicyos edulis* Jacq.

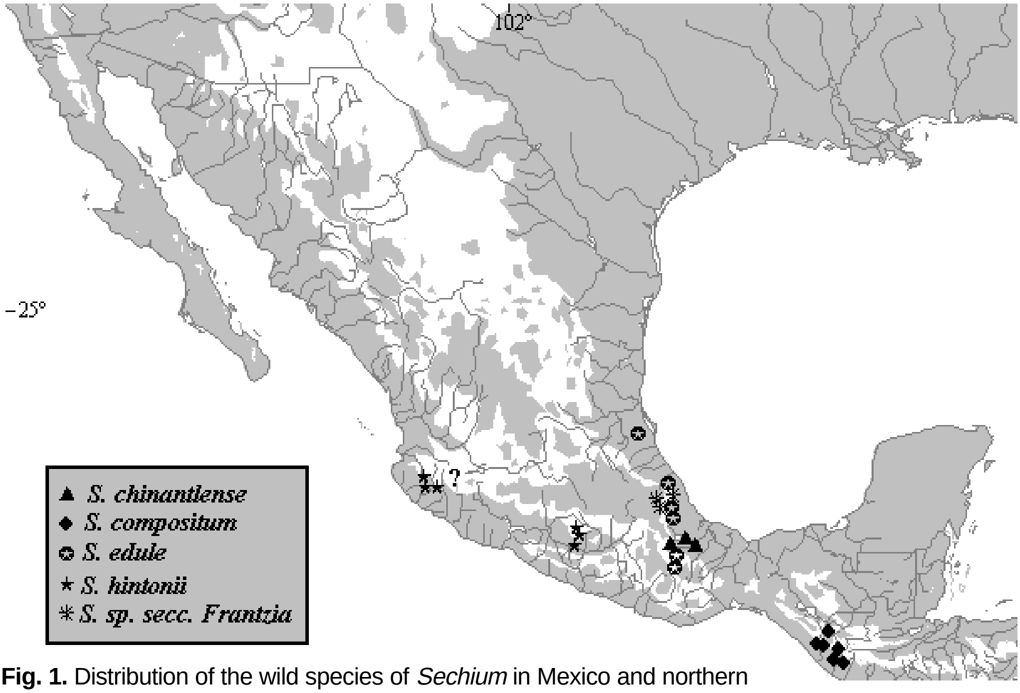

Fig. 1. Distribution of the wild species of *Sechium* in Mexico and northern Central America. Question mark indicates possible *S. hintonii* populations in Jalisco.

The following are accepted synonyms for this species: *Chayota edulis* Jacq., Sel. Stirp. Amer. tab. 245. 1780. *Sechium americanum* Poir., Lam. Encyc. Méth. Bot. 7: 50. 1806. *Cucumis acutangulus* Descourt., Fl. Méd. Antilles 5: 94. 1827. Non L., 1753. *Sicyos laciniatus* Descourt., Fl. Méd. Antilles 5: 103. 1827, non L., 1753. *Sechium cayota* Hemsley, Biol. Centr. Am., Bot. 1: 491. 1880.

2.3 Common names

Because chayote is so widespread throughout many regions of the world, and is so well known as a useful plant, it has come to be known by a wide variety of names in different languages. Newstrom (1986, 1991) made an excellent compilation of these, in addition to analyzing their geographical distribution in search of patterns that might suggest the centre of origin of this crop. More recently, additional names have been collected by Lira (1995a). Although all the above authors agree that the most widely accepted term is 'chayote', alternative names are given to this crop wherever it is cultivated.

In Mexico, for example, where numerous ethnic groups live in different states, chayote is also known by a vast variety of other names including: 'apupo', 'apopu' (Michoácan; Tarasco); 'niktin' (Oaxaca; Trique); 'naña' (Oaxaca; Mixteco); 'itú-tse', 'jit-jiap', 'yape' (Oaxaca; dialectal variations of Zapoteco found in Ixtlán, Tlacolula and the Isthmus of Tehuantepec); 'aj-shá' (Oaxaca; Mixe); 'rign', 'nñ' (Oaxaca; Chinanteco); 'mishi', 'cal-mishi' (Oaxaca; Chontal); 'tzihu', 'tzihub' (San Luis Potosí;

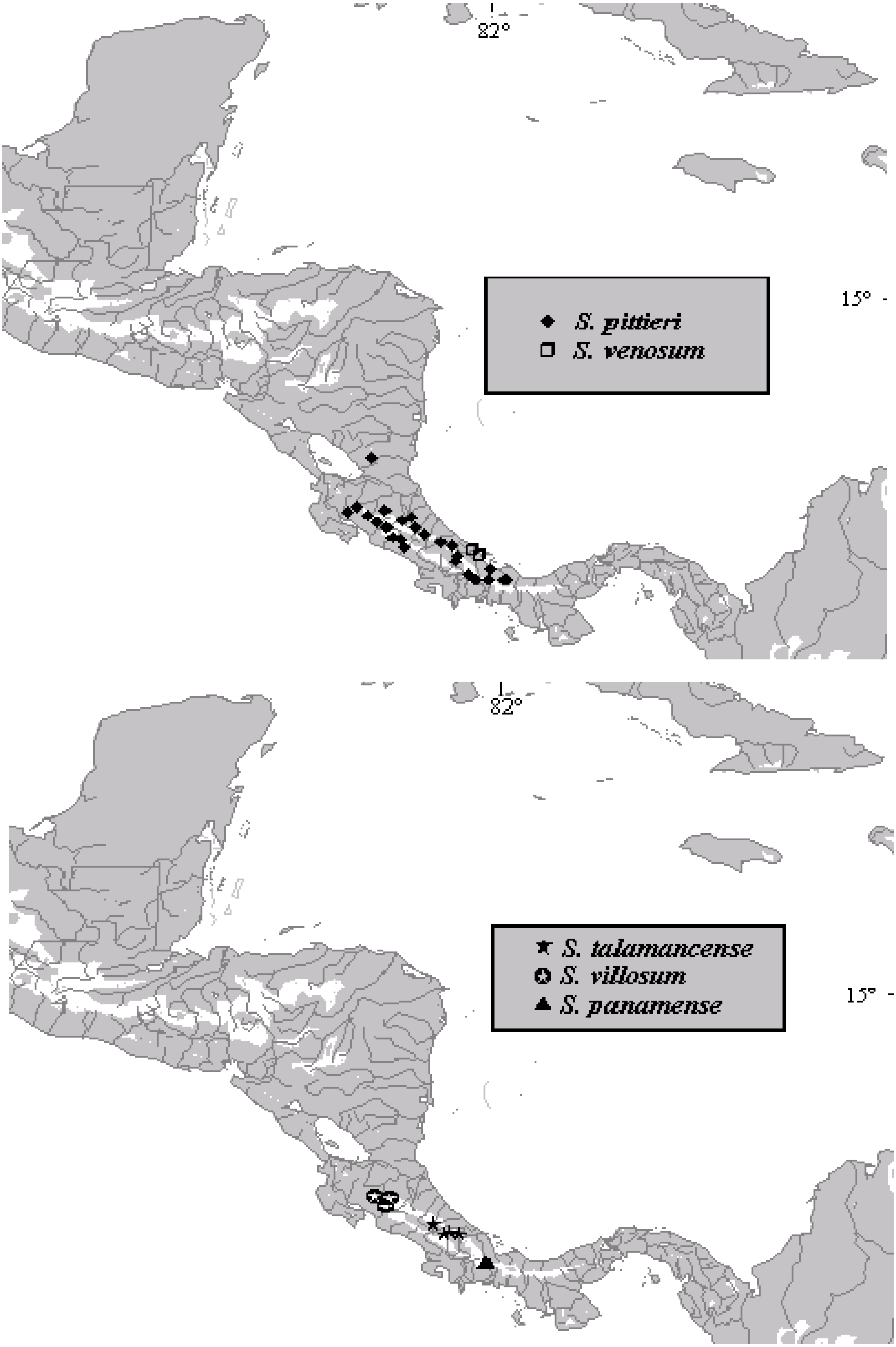

Fig. 2. Distribution of the wild species of *Sechium* in Central and southern Central America.

Huasteco); 'mú-u' (State of Mexico; Mazahua); 'shamú', 'xamú' (State of Mexico and Hidalgo; Mazahua); 'chayoj', 'chayojtli' (Puebla and Morelos; terms obviously derived from the original Nahuatl name); 'macltucún', 'multucún', 'huisquilitl', The wild varieties are known in Veracruz as 'chayotes de monte' and 'erizos de monte', and in Oaxaca as 'nñ' and 'rign-cuá', both terms of Chinanteco origin.In Central America, *S. edule* is known by several other names, as well as 'chayote'. In most of Guatemala and El Salvador, it goes by names such as 'güisquil', 'bisquil', 'huisquil', 'chuma', 'chima', 'chimaa', 'huisayote', 'güisayote' and 'perulero'. In the Alta Verapaz department of Guatemala, it is known as 'rasi cimá'. In Honduras, although it is known as 'huisquil', it is also called 'ñame', 'patasté' and 'patastilla', while in Nicaragua it is known as 'chaya'. In Costa Rica, its names include 'pís', 'pog-pog-iku', 'seuak', 'surú' and 'tsua-uá', all of which appear to derive from local indigenous languages.

In other regions of the American continent, the names given to this crop, as pointed out by Newstrom (1991), reflect the linguistic influence of colonialization. Thus, names very similar to and apparently derived from chayote or chuma are present in some Latin American countries. Examples of these are 'tayote', 'tayón', 'chocho' and 'chiote' in Cuba, Puerto Rico, the Dominican Republic and Jamaica; 'cidrayota' and 'chayota' in Colombia; 'gayota' in Peru; 'chayoto in Venezuela; 'cho cho', 'xuxu' or 'chuchu' in Brazil and several Caribbean countries; and 'cayota' in Argentina. In other instances, the names appear to derive from French. In Haiti and the American state of Louisiana, the term 'christophine' is used, while in Bermuda, French Guyana, Guadeloupe and again in Louisiana, the species is known as 'mirliton'.

In South America, the common names for 'chayote' appear to have been taken, in some cases, from other crops, which also sometimes, curiously enough, belong to the Cucurbitaceae family. In Argentina, for example, the crop is known as 'papa del aire' (air potato) and in Colombia, as 'papa de pobre' (poor man's potato), while in Bolivia, it is called 'zapallo' and in Ecuador, 'achocha', or 'achojcha'. The last two names are the same as those given to *Cucurbita maxima* Duch. ex Lam, and *Cyclanthera pedata* (L.) Schrad. in these and other South American countries. These two cultivated species belong to the Cucurbitaceae family, and are native to this area of the continent.

Outside the Americas, the 'chayote' is given names which clearly reflect those used in the places from which the plant was first introduced, although local names do sometimes exist. In Portugal, for example, it is known as 'chahiota', 'cahiota', 'caiota', 'pepinella' and 'pipinella, while in England, Australia, Madagascar, Reunion and Mauritius, it is called 'chocho' or names derived from this, such as 'choko', 'chocho', 'chowchow', 'chouchou' and 'chouchoute'. The Russian name for the plant is 'cajot'. On the other hand, in China, it is known as 'buddhas's hand', while in Italy, its common name is 'zucca' or 'zucca centenaria'. In several Asian countries, it is given local names, such as 'vilaiti vanga' (India), 'leong-siam' (Indonesia), 'labooh selyem' (Malaysia), 'labooh tjena' (Java), 'su-suu' (Kampuchea and Vietnam), 'savëëx', 'nooy th'ai' (Laos), and 'ma-kheua-kreua' and 'aeng-kariang' (Thailand).

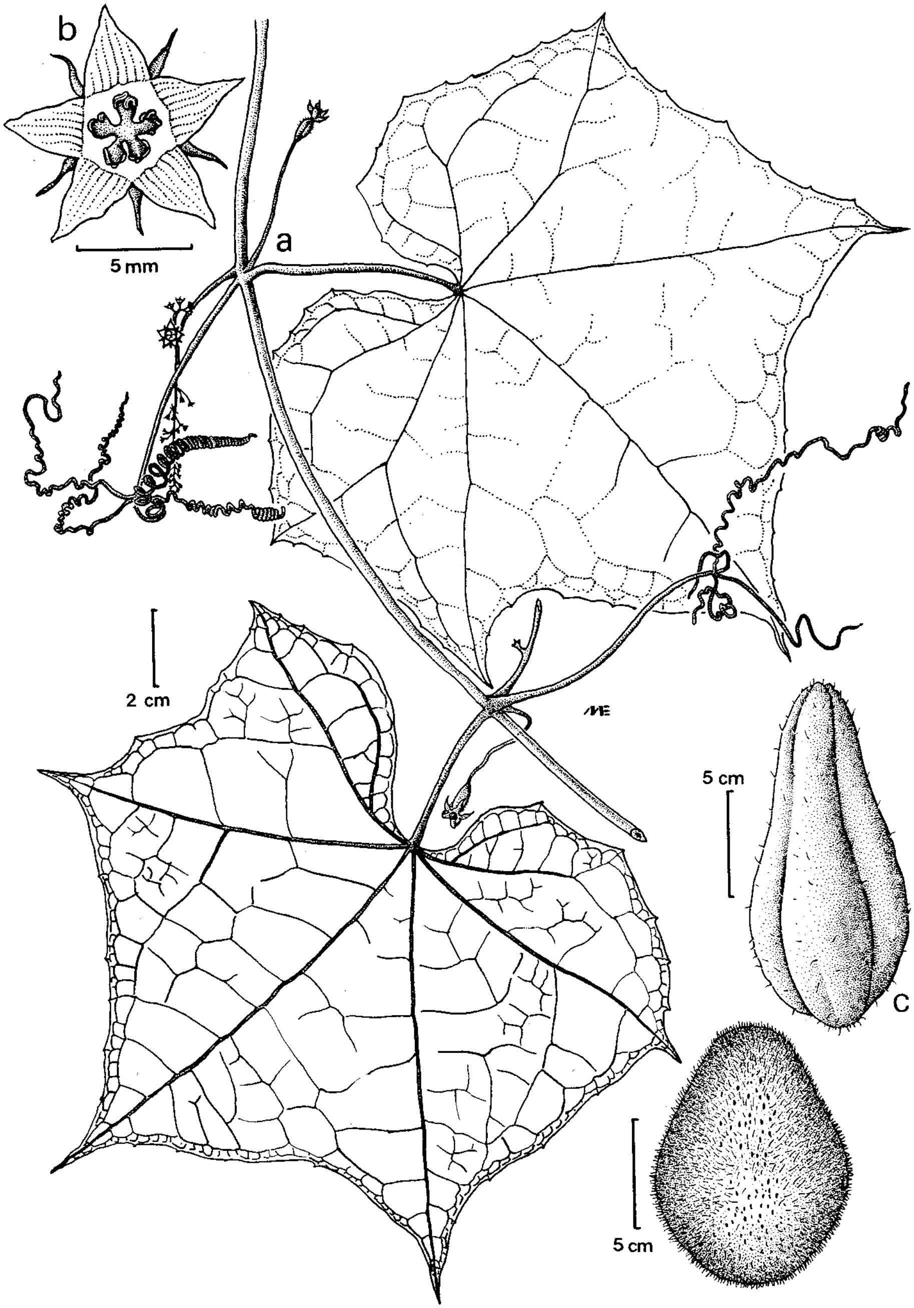

Fig. 3. *Sechium edule*: (a) branch with leaves, tendrils and staminate and pistillate flowers; (b) staminate flower; (c) fruits (Reprinted with permission from Nee 1993).

3 Brief description of the crop

3.1 Botanical description

The chayote is a herbaceous, perennial, monoecious, vigorous creeper or climbing plant (Fig. 3). It grows from a single, thick root, which produces adventitious tuberous roots (Fig. 4). The stems are angular-grooved and glabrous, and several grow simultaneously from a single root, at least in the cultivated plants. They thicken towards the base and appear woody, while towards the apex there are many thin, firm, herbaceous branches. The leaves have grooved petioles, 8-15 cm long, and are glabrous; the blade is a firm papiraceous-membranous, ovate-cordate to suborbicular, 10-30 cm long, and almost as wide at the widest point, slightly 3-5 angular-lobed with pointed to acuminate lobes, the margins are totally to slightly dentate, and the base is cordate-rectangular, with the sinus open to semiclosed by the bases of the lateral lobes (Fig. 3); both blade surfaces are pubescent when young, later becoming glabrescent, although the adaxial one is persistently puberulent on the veins. Like almost all Cucurbitaceae, the chayote plant develops tendrils for support. These are sturdy, 3-5 branched, furrowed and essentially glabrous.

The flowers are unisexual; the staminates are arranged in pedunculate and erect racemes, 10-30 cm long or more in wild plants, and usually with the flowers arranged in fascicular or subracemose clusters disposed at intervals along the rachis; the pedicels are 1-2 mm long and are puberulent; the receptacle is patelliform, 1-2 mm long or less, 4-5 mm wide and glabrous, with five narrow triangular sepals usually patent to reflexed in buds, which are 4 mm long and almost 1 mm wide. There are also five petals, patent, green to greenish-white, which are widely triangular, obtuse to acute, 6-7 mm long and 2-3 mm wide. The stamens are five with fused filaments along almost all of the length, forming a thick column, which normally separates into five short branches (although sometimes three, and more rarely four, are found) (Fig. 3); the

Fig. 4. Roots of chayote in a Mexican market.

anthers develop at the apex of the short branches of the filaments, they are oblong and when three are found, two of them are bithecous and one monothecous, and when there are more than three, apparently all are bithecous, the thecas are flexuous and the connective has some scattered short hairs with an enlarged base. A total of 10 pore-like uncovered nectaries are found at the base of the receptacle surrounding the staminal column. These are densely puberulent to tomentose on the upper surface, and only slightly projected beneath, in the form of a sac.

The pistillate flowers develop in the same axilla as the staminate ones. They are usually solitary, although occasionally they might grow in pairs or, on rare occasions, three grow from the same pedicel; the pedicel is thin, grooved, glabrous and is 1-3.5 cm long, growing up to 8-9 cm in the fruit. Many different shapes of ovary are found, from completely unarmed and glabrous to variously indumented or armed; the perianth is like that of the staminate flower, but reduced in the receptacle; the styles are joined together in a thin column, and the stigma is subglobose and 2-lobate; the nectaries of the receptacle base are similar to those of the staminate flowers.

Fig. 5. Export type of fruits.

Fig. 6. Diversity of fruits of cultivated *Sechium edule* found in the Mexican states of Chiapas and Oaxaca.

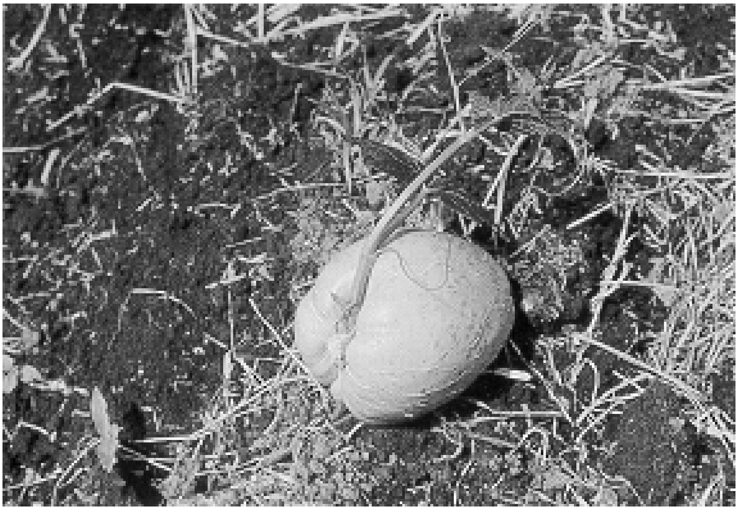

Fig. 7. Vivipary.

The fruits grow either individually or in pairs (rarely in greater numbers) on a shared peduncle (Fig. 5). They are fleshy or fleshy-fibrous, may have longitudinal ridges or furrows, and come in many different shapes (globose, ovoid, subovoid, pyriform, elongated pyriform), sizes (4.3-26.5 cm long, 3-11 cm wide), and colours (from white to pale yellow – colours not found in wild populations – to dark or light green) (Figs. 3, 6); they may be unarmed and smooth, or with varied indumentum or armature, although they generally conserve the characteristics of the ovary. They may have woody ridges or lenticels on the surface, especially when ripe; the pulp is pale green or whitish and tastes bitter in wild plants and pleasant, sweet or insipid in cultivated plants; the seed is ovoid, compressed and smooth, and germinates within the fruit (Fig. 7); in cultivated plants the seed germinates when the fruit is still on the plant, while in wild plants only once the fruit becomes detached.

A wide variation in the *S. edule* chromosome number has been documented in the literature. Some studies agree that the haploid and diploid numbers of this species are n=12 and 2n=24 respectively (Sugiura 1938, 1940; Sobti and Singh 1961; Goldblatt 1981, 1984), while others report accounts of n=13 and 2n=26 (Goldblatt 1990), 2n=28 (Giusti *et al.* 1978) or 2n=22 (Singh 1990).

3.2 Flower biology and pollinators

To judge from the number of detailed studies available, flower biology and pollinators must rank among the most researched auto-ecological aspects of *S. edule* (Martinez-Crovetto 1946; Merola 1955; Giusti *et al.* 1978; Wille *et al.* 1983; Newstrom 1986, 1989). Some of the conclusions reached by these studies are of relevance to chayote cultivation and conservation. Among cultivated types, for example, variations have been found in the sexual rate of production of staminates and pistillate flowers. These appear to be the result of genetic, environmental and seasonal factors, as well as the age of the plant. A better understanding of these factors would be important when improving the crop, and, in particular, in the selection of types with high productivity of female flowers and, therefore, of fruits.

As far as pollination is concerned, it is known that this is carried out by several insect species. Additionally, there appears to be no difference in fruit production rates between plants with open pollination and those which are self- or cross-pollinated (Newstrom 1986; Ramírez *et al.* 1990). On the other hand, it seems that fruit production is not affected by the number of pollen grains applied to the stigma, or by how often they are applied. It also has been shown that when chayote was grown under greenhouse conditions, in the absence of pollinating insects, immature fruits failed to develop and abscised prematurely (Aung *et al.* 1990).

The fact that chayote pollination depends on insects may be one of the reasons why it has spread so successfully, but it also makes it very difficult to preserve pure strains, which is important not only for commercial or traditional plantation, but also for genebanks. The relative importance of chayote pollinators has been observed to increase not just with ecogeographical and environmental factors such as altitude and latitude, but also with the use of pesticides (Giusti *et al.* 1978; Wille *et al.* 1983; Newstrom 1986). Thus, some species of bees of the genus *Trigona* that have been identified as very efficient chayote pollinators are found mostly at medium to high altitudes, which are pesticide-free. In contrast, other important pollinators, such as *Apis mellifera,* are most commonly found mainly in commercial plantations, where pesticides are frequently used. Secondary pollinators of chayote include wasps from the genera *Polybia, Synoeca* and *Parachrataegus* as well as other smaller species of *Trigona*.

4 The origins of chayote

Unlike that which exists for many other crops, there does not appear to be any archaeological evidence to establish how long *S. edule* has been cultivated. It seems that the fleshy fruit, with its single soft testa seed, does not lend itself to conservation and, until now, the presence of pollen grains or other structures of this species at archaeological sites has not been reported. Instead, the most commonly used sources for establishing the possible origin of this crop have been ethnohistoric, artistic and linguistic, together with information on the ecogeographic distribution of the genetic diversity of both the wild and cultivated species.

From the ethnohistorical record, we know that, at least in Mexico, chayote has been cultivated since pre-Colombian times. The first description of chayote was probably that of Francisco Hernández, who was in Mexico from 1550 to 1560 (Cook 1901), but the crop was not introduced into the southern part of the continent until after the arrival of the Spanish (Newstrom 1986, 1991). Linguistic evidence for this is provided by the common names given to the species in different parts of Latin America. These clearly indicate that the species was originally concentrated in Mexico and Central America. In many cases, these same names (especially that of Nahuatl origin, 'chayote') with only slight modifications, are used in other areas of the world where the species was introduced. Pre-Colombian decorated pottery has been found in Mexico and Central America which clearly depicts chayote (Pérez 1947 in Newstrom 1991).

It is the ecogeographic distribution of *S. edule* under cultivation, and that of its wild relatives, however, which provides the greatest evidence for establishing the centre of origin of this crop. Reports of explorations carried out during different periods by various people and institutions (León 1968; Bukasov 1981; Engels 1983; Maffioli 1983; Cruz-León and Querol 1985; Newstrom 1985, 1986; Lira 1995a) all concur that the widest variety of cultivated chayote is found in southern Mexico, Guatemala and Costa Rica, at altitudes of 500-1500 m.

As far as the distribution of the wild species and its relation to chayote is concerned, there appears to be little doubt that the crop must have originated in this area. As shown above, most of these species, and especially those most morphologically similar to chayote, are known to grow within the geographic and altitude limits mentioned previously. The wild taxa of *Sechium* that are morphologically closest to chayote include the so-called 'wild types' of *S. edule* which grow in the southern part of Mexico, and Lira and Chiang (1992), a recently described endemic species from the north of the State of Oaxaca (Fig. 8), which was previously identified simply as a wild type of chayote (Newstrom 1985, 1986, 1990, 1991).

Both taxa have staminate flowers, which are very similar to those of cultivated chayote (naked nectaries at the base of the receptacle, and partially joined filaments and side branches, with anther tissue at the apex), and fleshy fruit with very bitter pulp. Furthermore, they are the only members of the genus which, like those of *S. edule*, have a cleft at the apex from which the plantule sprouts once the seed has

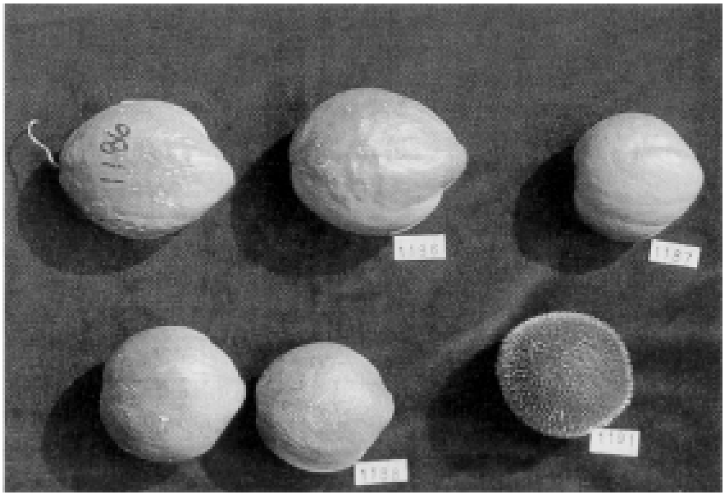

Fig. 8. Fruits of wild *Sechium edule* (spiny) and *S. chinantlense* (unarmed).

germinated. It has been suggested (Newstrom 1986, 1990) that the bitter taste of the fruit is probably due to the presence of high concentrations of cucurbitacines. These secondary chemical compounds of the plant are very frequent among the members of the Cucurbitaceae family, and are considered to be among the most bitter substances known. They appear to serve as a defence against herbivores (Metcalf and Rhodes 1990).

Another two species that are morphologically similar to chayote are *S. compositum* and *S. hintonii* (Figs. 9, 10); the former is endemic to the states of Mexico and Guerrero (Wilson 1958; Lira and Soto 1991; Lira 1995a, 1995b) and the latter is only known from the Mexican state of Chiapas and neighbouring areas of Guatemala (Donnell-Smith 1903; Standley and Steyermark 1944; Dieterle 1976; Lira 1995a, 1995b). These two species are similar to cultivated chayote in their floral nectary and androecium structure, but their fruit, although also fibrous and bitter, do not have the apex cleft mentioned above. The remaining wild species of *Sechium* are morphologically more similar to the other cultivated species, *S. tacaco*, and, apart from the as yet undescribed species from Veracruz (Nee 1993), they all grow in southern Central America (from Nicaragua to Panama) (Pittier 1910; Wunderlin 1976, 1977, 1978; Gómez and Gómez 1983; Newstrom, 1986, 1990, 1991; Lira and Chiang 1992; Lira 1995a, 1995b).

The importance of these wild taxa as genetic resources and their relationships with the cultivated chayote must be verified. Further studies need to be carried out on cross-breeding between many of these species and chayote and, of course, their potential for improving it should be determined. There follows below a synthesis of what is known about those taxa, which appear to be most related to chayote. In addition, some characteristics with potential for use as genetic resources are highlighted.

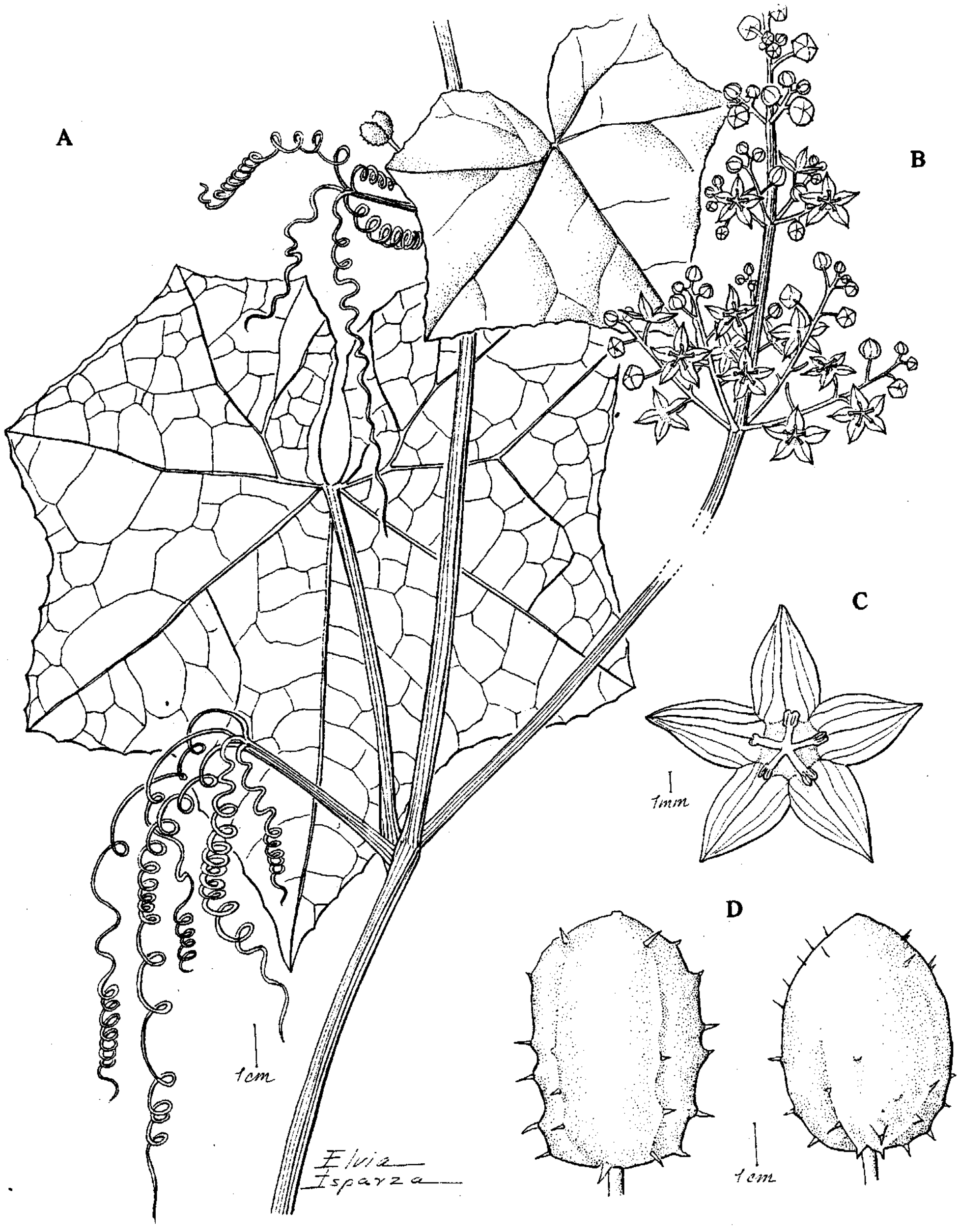

Fig. 9. *Sechium compositum.*

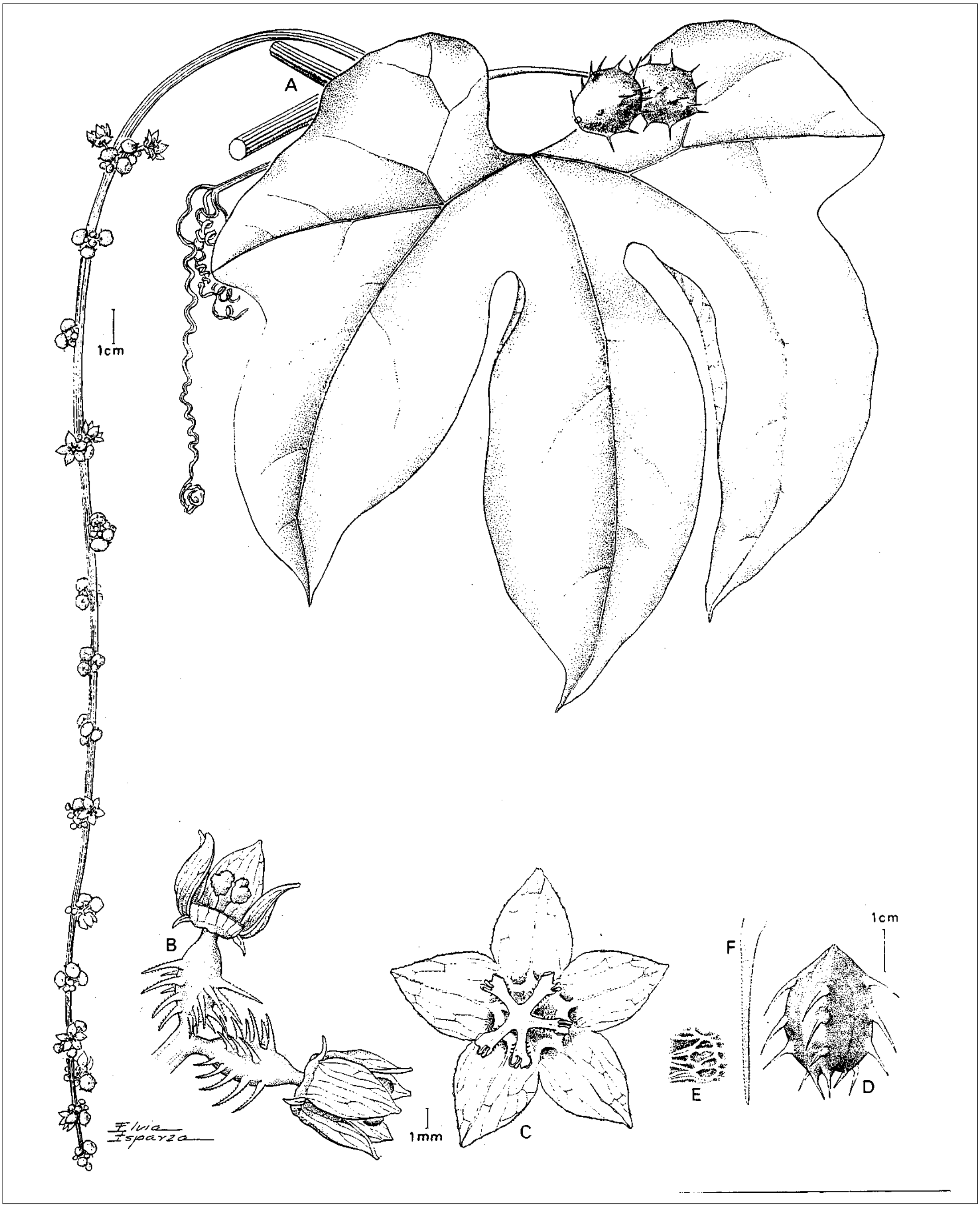

Fig. 10. *Sechium hintonii.*

4.1 *Sechium edule* wild types

Ecogeographical distribution The 'wild' types of *S. edule* mentioned here were registered and classified as such by Cruz-León (1985-86) for the State of Veracruz, on the Gulf of Mexico, and were later reported in the State of Oaxaca by Newstrom (1985, 1986, 1989, 1990). It is now known that this type of population thrives in the States of Veracruz, Puebla, Hidalgo and Oaxaca (Lira 1995a, 1995b; Fig. 1) in southern Mexico, at heights of 500-1700 m asl, where plants can be found in huge, thick clusters. Typical habitats for these plants are damp areas such as ravines, waterfalls and rivers or streams, where the vegetation is predominantly montane rainforest. They are also found in the lower parts of ecotone zones with evergreen or semi-evergreen seasonal forest.

Although some presumably wild populations of *S. edule* have been reported from the island of Java, Reunion (Backer and Bakhuizen 1963, Cordenoy 1895), and in some parts of Venezuela (Brücher 1989), these reports have yet to be confirmed, as they have not been backed up by collections. It is also possible, at least in the case of Venezuela, that these populations might have resulted from plants escaped from cultivation (C. Jeffrey 1991, pers. comm.; L. López 1991, pers. comm.).

Intraspecific variation Wild types of *S. edule* have very similar (or in some cases almost identical) morphological characteristics to those of the cultivated types of this species. The flowers of these plants, for example, although slightly bigger than those of cultivated plants, have an identical staminal structure. Their fruit also has an apex cleft from which the plantule sprouts, once the seed has germinated.

The most significant morphological differences between cultivated and wild chayote are the difference in size of the vegetative and reproductive structures. Wild plants are more robust, for example, and their leaves, flowers and staminate inflorescence are bigger than those found in cultivated plants. On the other hand, as will be seen below, although the fruit of most of the populations of the State of Veracruz have a different morphology, strict comparisons between this species and cultivated types are obviously not possible. Yellow or white fruits, for example, have not been recorded for these plants. Moreover, as pointed out above, the pulp has a bitter taste and is usually more fibrous.

Such differences are even more accentuated in the populations from Oaxaca. The fruits, as well as having fibrous pulp and a bitter taste, are more homogeneous in shape (globulate), colour (dark green) and prickles (very prickly) (Lira 1995a, 1995b). Another important difference between these wild populations is their chromosome number: for those of Veracruz the haploid number reported is n=12 (Palacios 1987), while for those of Oaxaca the haploid number of n=13 has been determined (Mercado *et al.* 1993; Mercado and Lira 1994). According to Newstrom (1991), the morphological variation of the populations of Veracruz, their proximity to cultivated areas, and the fact that six fruits have been obtained from experimental that these populations could be of hybrid origin.

Phenology Wild populations of *S. edule* flower from April to December and give fruit from September to January.

Potential importance Studies have not been carried out on the potential these plants might have as a resource for improving chayote. However, given their morphological similarity, and their potential for successful hybridization with cultivated chayote plants, these populations should be among the first to be evaluated, especially for resistance to disease and pests. Hybridization programmes with cultivated types should clearly be started.

4.2 *Sechium chinantlense* Lira & Chiang

Ecogeographic distribution This species is endemic to a very small region of Mexico, in the north of the State of Oaxaca, near the boundary with the State of Veracruz (Fig. 1). It thrives at altitudes of 20-800 m. In lower-lying areas, it grows in rainforest, and in higher zones in the ecotone with montane rainforest. The *S. chinantlense* species should be placed on the list of endangered species, since natural vegetation in the very restricted areas where it is found is currently seriously threatened.

Representative material from the populations of this species was first collected by G. Martínez-Calderón between 1940 and 1941 (G. Martínez-Calderón 369, 458, 826 in GH, MICH and MEXU) and R. McVaugh in 1962 (R. McVaugh 21801 in MICH) and were identified as *Ahzolia composita* (J.D. Smith) Standley and Steyermark. Years later, Newstrom (1986, 1989, 1990, 1991) included them in 'wild types III' of *S. edule*. She pointed out that the characteristics of their staminate flowers, the presence of smooth fruit and some of their chemical properties indicated a close relationship to *S. compositum*. She also suggested that they might have resulted from hybridization between this last species and cultivated types of chayote. However, it was precisely the structure of the stamens of these plants, the morphological and biological characteristics of the fruit (with germination apex cleft), and their reproductive incompatibility with cultivated and wild plants of *S. edule* (Castrejón and Lira 1992), which permitted them to be identified as a new species (Lira and Chiang 1992). The fact that *S. compositum* is not found in Oaxaca does not indicate that it is a plant of hybrid origin, at least not a hybrid between this and any other species in the genus.

Phenology *Sechium chinantlense* flowers from August to November and gives fruit from September to February. In the southern part of its area of distribution, the phenological effects are seen earlier than in the populations found further north, where it is lower and drier. Thus, in the former areas, flowering begins in August, and fruit from October to December, while in the latter areas, flowering does not begin until November, and fruit can be found from December to February.

Common names This species is known in Spanish as 'cabeza de chango', 'chayote cimarrón' and 'chayote de monte', and in Chinanteco as 'nñ', 'rign-cua' and 'rign-kiu-moo'.

Potential importance The plants of this species are found in areas with high relative humidity, and, as mentioned above, there is a phenological variation which is apparently related to the microclimatic differences of the places where its populations grow. However, whether these characteristics are important for the improvement of chayote has still to be determined. Although detailed studies do not exist on the crossability of *S. chinantlense* with *S. edule*, preliminary data from Castrejón and Lira (1992), show that hybrids cannot be obtained from these two species. It may be that they are not crossable, because of the difference in their chromosome number. For *S. edule*, diploid numbers of $2n$=22, n=24 and n=26, among others, have been registered, while for *S. chinantlense*, a diploid number of $2n$=30 (Mercado *et al.* 1993) has been reported.

4.3 *Sechium compositum* (J.D. Smith) C. Jeffrey

Ecogeographic distribution Distribution of *S. compositum* covers some of the southern part of the State of Chiapas in Mexico, as well as neighbouring areas in Guatemala (Quetzaltenango, Escuintla and Suchitepequez) (Fig. 1). This species is found at a wide range of altitudes (50-2100 m), on sites which usually contain ravines, riverbanks and waterfalls. Vegetation may be primary or secondary, derived from montane rainforest or evergreen or semi-evergreen seasonal forest. It is also frequently found growing in coffee plantations. Many *S. compositum* populations have been found in the south of Mexico, in the State of Chiapas, within the confines of the Biosphere Reserve 'El Triunfo', thereby ensuring its conservation under natural conditions (Lira 1995a, 1995b).

Intraspecific variation The *S. compositum* fruits have been described in the literature as longitudinally ridged, with prickles on the ridges (Dieterle 1976; Donnell-Smith 1903). However, during field work in Chiapas and Guatemala, some populations were found with fruit, as described in the literature, while others were completely smooth and unarmed (Lira 1995a, 1995b).

Phenology This species flowers from September to January, and presents fruits from October-November to February.

Common names *S. compositum* is known by several common names, most of which are similar to those of *S. edule*. Thus, in Chiapas, it is known mainly as 'chayote de caballo,' or 'huisquil de cochi' and also as 'xmasil' or 'xmasin', both of Máme origin, but the meanings of which are unknown. In Guatemala, names such as 'huisquil de monte' have been recorded, and Dieterle (1976) reports the name 'huisquil de ratón' (for *Ahzolia composita*).

Uses In Chiapas, the chopped-up roots are mixed with water, and used as a soap substitute and to kill horse fleas. Moreover, some of the common names (‘chayote de caballo’, ‘chayote de burro’ and ‘huisquil de cochi’) seem to suggest that the fruit, in spite of being bitter and possibly having a high cucurbitacines content, could be used for consumption by domesticated animals.

Potential importance The fruit of *S. compositum* can be stored for several months, with no recorded effect on turgidity or humidity. Attempting to incorporate this characteristic into cultivated chayote may be of interest in solving storage or conservation problems. Cross-breeding between this species and cultivated chayote has not been explored. However, a hybrid plant obtained from the cross between *S. compositum* and a cultivated plant of *S. edule* has been reported. This plant even produced fruit in the CATIE genebank in Costa Rica (Newstrom 1986). It should be pointed out that the haploid chromosome number of this species is *n*=14 (Mercado *et al.* 1993; Mercado and Lira 1994).

4.4 *Sechium hintonii* (P.G. Wilson) C. Jeffrey

Ecogeographic distribution *Sechium hintonii* is a species endemic to a small area of Mexico. Until a short time ago, it was only known from the types collected within the Temascaltepec District in the State of Mexico. Recently, it was rediscovered on a site near one of these localities (Lira and Soto 1991) and, shortly afterwards, a small population was found a little further south, in the State of Guerrero (Lira 1995a; Fig. 1). This species has been found on sites at altitudes of 1300-1510 m asl, in a climatic-vegetation transition zone. The climate in this region is hot to semi-hot. The site in the State of Mexico could be described as an ecotone, between deciduous seasonal forest and *Quercus* forest, but it is seriously threatened by seasonal agricultural activities. Although the vegetation in the Guerrero site is similar, it appears to have more in common with the deciduous seasonal forest, and it is in a much better state of conservation than that of the State of Mexico.

A few specimens from sites located in the municipalities of Autlán and Cuautitlán, in the State of Jalisco in western Mexico (Wilbur 2456, McVaugh 19958 in MICH, Vázquez 4069, Cuevas and López 3247 en ZEA), could belong to this species. They do, however, differ in some respects from the most typical samples, mainly in the size of the fruit and the pedicels of the staminate flowers, as well as in the outline of the leaves and the shape of the lobules. Other characteristics of the fruits also differ (they are smaller with prickles only at the base, and they do not have backward-turning prickles). If this material could be identified as belonging to *S. hintonii*, then its area of distribution would be widened considerably towards the northwest. A recent visit to the sites failed to do this, however, which is unfortunate, since the vegetation is in a far better state of conservation than in the States of Mexico and Guerrero (Lira 1995a, 1995b).

Phenology *Sechium hintonii* flowers from August to November, and produces fruit from October to December. Field observations revealed that the aerial parts of this species dry after December, but sprout again the following year in April, just before the start of the rainy season.

Common names In the State of Mexico, it is known as ‘chayotillo’.

Potential importance No information is available and all that can be said is that, as in the case of wild types of *S. edule*, this species could be a source of resistance to diseases and pests. It is not known, unfortunately, whether it can be crossed with chayote. All that is known in this respect is that its haploid chromosome number is n=14 (Mercado *et al.* 1993; Mercado and Lira 1994). *Sechium hintonii* is clearly an endangered species, as it is endemic to a relatively small area, with known populations that thrive only in areas which are currently seriously affected by deforestation and agricultural activities. In addition, germplasm collections which would at least guarantee its conservation *ex situ* do not exist.

5 Uses and properties

Chayote is basically used for human consumption, not just in the Americas but in many other countries. In addition to the fruit, stems and tender leaves (usually known as 'quelites'), the tuberous parts of the adventitious roots (in Mexico called 'chayotextle', 'cueza', 'camochayote', 'chayocamote' and 'chinchayote', and in Guatemala and El Salvador 'ichintla', 'echintla', 'chintla' or 'chinta') are also eaten. They are much appreciated as a vegetable and are either just boiled or used in stews and desserts (Cook 1901; Terraciano 1905; Mattei 1907; Hoover 1923; Lionti 1959; Ory *et al.* 1979; Bukasov 1981; Williams 1981; Esquinas and Gulick 1983; Orea-Coria and Englemann 1983; Cruz-León 1985-86; Cruz-León and Querol 1985; Newstrom 1985, 1986, 1990, 1991; Dubravec 1986; Lira 1988; Flores 1989; Walters 1989; Aung *et al.* 1990; Chakravarty 1990; Lira and Bye 1992; Yang and Walters 1992; Engels and Jeffrey 1993; Lira and Torres 1993; Baral *et al.* 1994; Cheng *et al.* 1995; Sharma *et al.* 1995).

Table 3. Chemical composition (% or mg/100 g) of fruit, young stems and roots of *Sechium edule*

Component	Fruit	Seed	Stem	Root
Calories	26.0-31.0	–	60.0	79.0
Humidity (%)	89.0-93.4	–	89.7	79.7
Soluble sugar (%)	3.3	4.2	0.3	0.6
Starch (%)	0.2	1.9	0.7	13.6
Proteins (%)	0.9-1.1	5.5	4.0	2.0
Fats (%)	0.1-0.3	–	0.4	0.2
Carbohydrates (%)	3.5-7.7	60.0	4.7	17.8
Fibre (%)	0.4-1.0	–	1.2	0.4
Ashes (%)	0.4-0.6	–	1.2	1.0
Ca (mg)	12.0-19.0	–	58.0	7.0
P (mg)	4.0-30.0	–	108.0	34.0
Fe (mg)	0.2-0.6	–	2.5	0.8
Vitamin A (mg)	5.0	–	615.0	–
Thiamin (mg)	0.03	–	0.08	0.05
Riboflavin (mg)	0.04	–	0.18	0.03
Niacin (mg)	0.4-0.5	–	1.1	0.9
Ascorbic acid (mg)	11.0-20.0	–	16.0	19.0

Sources: Engels 1983; Aung *et al.* 1990.

The edible parts of *S. edule* (Table 3) are relatively low in fibre, protein and vitamins compared with other vegetables. Nevertheless, they have a high caloric and carbohydrate content, especially in young stems, root and seed, and the micro and macronutrient content of the fruit is adequate. The fruits, and the seed especially, are rich in several important amino acids such as aspartic acid, glutamic acid, alanine, arginine, cistein, phenylalanine, glycine, histidine, isoleucine, leucine, methionine (only in the fruit), proline, serine, tyrosine, threonine and valine (Flores 1989). Many of these nutritional characteristics make chayote particularly suitable for hospital diets (Liebrecht and Seraphine 1964; Silva *et al.* 1990).

Chayote is also used in other ways in different parts of the world. The softness of the fruit flesh makes it particularly suitable for giving consistency to baby foods, juices, sauces and pastes. Because of the flexibility and strength of the stems, they are used in some places, such as Reunion, in handicrafts to make baskets and hats (Cordenoy 1895 in Newstrom 1991). In India, as in the Americas, the fruit and roots are not only used as food but also as fodder for cattle (Chakravarty 1990).

Medicinal use of chayote has also been documented in the literature. Data compiled in recent studies highlight the use of decoctions made from the leaves or fruits to relieve urine retention and burning during urination or to dissolve kidney stones, and as a complementary treatment for arteriosclerosis and hypertension (Lira 1988; Flores 1989; Yang and Walters 1992). In the Yucatan Peninsula, where kidney disorders are frequent, these decoctions are considered to be effective and have been in use since colonial times (Lira 1988). The diuretic properties of the leaves and seeds, and the cardiovascular and anti-inflammatory properties of the leaves and fruit, have been confirmed by pharmacological studies (Bueno *et al.* 1970; Lozoya 1980; Salama *et al.* 1986, 1987; Ribeiro *et al.* 1988).

Dehydration of the fruit has been carried out in Mexico and other countries in an attempt to increase the shelf life of chayote and make it more widely available, perhaps even for industrial use (A. Cruz-León, pers. comm.). Results are said to be promising; jams and other types of sweets have been manufactured and dehydrated fruits have been conserved for later use as a vegetable. On the other hand, some countries, such as the Philippines, have successfully used chayote plants in mixed plantations designed specifically for soil recovery and/or conservation (Costales and Costales 1985).

6 Diversity and genetic resources

Few cultivated species produce fruits with such diverse morphology, mainly with regard to form, size, surface texture and, to a lesser degree, colour. In addition to this morphological diversity, chayote also has been documented as having a yield which varies considerably. All this would seem to point to the fact that this genus appears to have enormous potential for genetic resources. However, very little is known in this field, mainly because experimental materials are needed and, until now, efforts to conserve and study these resources have had less than satisfactory results. The endocarpic and precocious germination of the *S. edule* seed seriously hinders these tasks because it means that conservation cannot be carried out using orthodox methods. Instead, this has to be done in field genebanks which are expensive and complicated to administer and maintain, or *in vitro*. In spite of this, during the 1980s, several institutions showed interest in developing germplasm banks in order to conserve and study mainly cultivated chayote plants, but also some of its wild relatives. This section attempts to give a general overview of the diversity documented for the plants in these collections as well as of the few samples of what might be some of its closest relatives.

The morphological characteristics of cultivated chayote fruit are the most obvious sign of its diversity. Different authors have attempted to catalogue this variation which also has been useful in indicating the place of origin of chayote. Jacquin (1788), for example, said there were two cultivated types in Cuba, ‘chayote’ and ‘chayote francés’. Herrera (1870) gave different names to cultivated Mexican chayotes. Although he did not describe them, the names he chose obviously reflected the more salient characteristics ‘chayote pelón’ (bald chayote), ‘chayotito’ (small chayote) and ‘chayotito gachupín’ (well-bred or elegant chayote).

In Puerto Rico, Cook (1901) distinguished five different varieties of fruit with varying combinations of shape and colour (round white, long white, pointed green, broad green, oval green). Years later, Guzmán (1947) reported two varieties from El Salvador with fruit of different colours (white and green) while Whitaker and Davis (1962) said that there were 24 varieties in Guatemala with fruits of different shapes, colour and surface texture. More recently, León (1968) showed that the greatest variety is to be found between Guatemala and Panama, where there are at least 25 varieties.

However, these and other attempts to classify the diversity of cultivated chayote were never based on systematic collections and so the variation observed was not completely representative. A wider sample of chayote variation was not studied, catalogued and classified more systematically until the beginning of the 1980s. This was possible thanks to several collecting efforts (Engels 1983; Maffioli 1983; Cruz-León and Querol 1985; Newstrom 1985, 1986), which resulted in the setting up of the two most important germplasm collections to date. One of these was located in the CATIE in Turrialba, Costa Rica, and the other was in the Regional University Centre in Huatusco, Veracruz, Mexico. Duplicates of some of these collections are known to have been sent to the Institute for Forestry and Farming Research, in

Guanajuato, Mexico (Newstrom 1986; Bettencourt and Konopka 1990).

Unfortunately, factors such as frost, drought and root disease, together with the difficulties involved in handling the physical and biological variables (control of pollination for example) gradually led to the decline of these collections. According to Newstrom (1986), between 1975 and 1980 the CATIE collection grew to 375 accessions, mostly from Costa Rica, Guatemala and Honduras. This number, however, was reduced to almost half by 1981 (202 accessions according to Newstrom, 1986) and, although there was a slight increase in 1983 (215 according to Engels, 1983), in 1985 the number was reduced drastically to 111 (Newstrom 1986). The same thing happened to the Mexican collections and between 1988 and 1991, the three collections were destroyed, apparently because of lack of funds for their upkeep (Cruz-León, pers. comm.).

According to a recent directory of germplasm collections (Bettencourt and Konopka 1990), another two institutions also conserve (or have conserved) collections of cultivated *S. edule*; one of these is the Campos Azules Experimental Centre of the Higher Institute of Farming Sciences of Nicaragua (12 accessions of apparently local Nicaraguan types), and the other is the National Centre of Plant Research-EMBRAPA in Brazil (50 accessions of local Brazilian types). Unfortunately, this is all that is known about these two collections. In the references, no additional information is given on activities or the current state of the collections, although Brenes (1996) points out that the Brazilian collection also has disappeared. These losses are unfortunate, since at some point these genebanks between them housed more than 500 accessions. Most of them came from traditional market gardens in the west, centre, south and southeast of Mexico as well as from Brazil and several Central American countries (mainly Costa Rica and Guatemala), as well as some obtained from commercial plantations.

Fortunately, some detailed studies were published (Engels 1983; Maffioli 1983; Cruz-León and Querol 1985; Newstrom 1985, 1986) documenting the variation in the samples collected in Mexico and Central America and making it possible to analyze this. A summary of the most relevant data is given in Table 4. It can be seen that these collections were, without any doubt, very representative of the diversity of this crop since they included samples from different areas of Mexico and Central America where this crop has originated and developed its distinctive features.

In addition, the characteristics of the samples discussed in the above-mentioned studies show the significant variation of external features of the fruits such as colour, shape, size and number of spines and/or lenticels present on the surface. In some cases (Maffioli 1983; Cruz-León and Querol 1985; Newstrom 1986) information is given on the internal characteristics of the fruit such as fibre content and consistency of the flesh, and reference is also made to plant productivity (Cruz-León and Querol 1985) and even to the taste of the fruit flesh (Cruz-León and Querol 1985; Newstrom 1986). Although these collections were intended mainly to conserve the diversity of cultivated *S. edule* plants, the Costa Rica collection also had one *S. compositum* and several *S. tacaco* accessions, while that of Huatusco managed to

Table 4. Summary of the variation for the most important characteristics* of chayote fruits and plants from México and Central America, as recorded in the germplasm collections from Mexico and Costa Rica

	Costa Rica	Guatemala	Honduras/Panama	México
Length (cm)	4.8-26.5	4.9-16.4	7.1-15.9	4.3-25.0
Width (cm)	4.7-19.3	4.6-11.6	6.6-10.9	3.0-12.6
Thickness (cm)	4.4-11.0	4.3-8.7	6.8-9.9	2.7-10.2
Weight (g)	58-1207	48-540	299-398	61-1211
Volume (cm^3)	n.a.	n.a.	n.a.	47-1227
Colour	white, **light green**, dark green	white, **light green**, dark green	**light green**, dark green	white, yellow, **light green**, **dark green**
Shape	pyriform, **subpyriform**, ovoid, flattened, spheroid	pyriform, **subpyriform**, ovoid, flattened, spheroid	pyriform, **subpyriform**, ovoid, spheroid	elliptic, pyriform, subpyriform, ovoid, obovoid
Spines	absent, **few, intermediate**, many	absent, **few, intermediate,** many	**few, intermediate,** many	absent, **few**, **intermediate**, **many**
Furrows	absent, **shallow**, intermediate, deep	absent, **shallow**, intermediate	**shallow, intermediate**, deep	**shallow, intermediate**, deep
Ridges	n.a.	n.a.	n.a.	**absent, few**, intermediate, many
Lenticels	absent, **few**, **intermediate**, many	absent, **few, intermediate**	**few, intermediate**, many	**absent**, **few**, intermediate, many
Texture of pulp	n.a.	n.a.	n.a.	**solid, soft**
Taste of pulp	n.a.	n.a.	n.a.	**simple, sweet**, insipid**,** tasty, salty
Fibres of pulp	n.a.	n.a.	n.a.	absent, **few**, many
Days to harvest	n.a.	n.a.	n.a.	102-331
Fruits/plant	n.a.	n.a.	n.a.	49-521

* The most common data found for each characteristic are printed in **bold**.
n.a. = not available.
Sources: Engels 1983; Maffioli 1983; Cruz-León and Querol 1985; Newstrom 1985, 1986.

Table 5. Summary of the variation recorded for 11 fruits, collected in wild populations of *Sechium edule* from Veracruz, Mexico.

Length (cm)	Width (cm)	Thickness (cm)	Weight (g)	Volume (cm^3)	Shape	Colour of skin	Taste	Fibres	Distribution of spines
7.1	6.2	4.7	109.9	106.7	pyriform	light green	bitter	many	entire fruit
8.1	6.8	5.3	155.7	152.7	spheroid	dark green	bitter	many	no spines
9.1	5.6	4.7	116.8	114.0	oblong	dark green	bitter	many	entire fruit
7.6	5.6	4.8	108.7	106.8	pyriform	dark green	bitter	few	entire fruit
7.2	5.7	4.8	104.3	102.2	spheroid	light green	bitter	many	entire fruit
8.5	6.4	5.1	132.8	129.1	pyriform	dark green	bitter	many	entire fruit
7.5	6.0	4.9	114.6	113.0	pyriform	dark green	bitter	many	entire fruit
7.7	6.6	5.3	144.2	140.8	spheroid	dark green	bitter	few	entire fruit
7.8	5.2	4.2	94.8	93.6	pyriform	dark green	bitter	few	no spines
5.9	5.2	4.6	79.4	77.7	spheroid	dark green	bitter	few	apex
6.1	5.6	4.5	87.3	85.0	spheroid	light green	bitter	many	no spines

Source: Cruz-León and Querol 1985.

conserve several representative plants from wild *S. edule* populations from Veracruz. These were also described and a certain degree of diversity was found in the characteristics of the fruit (Table 5).

The analyses carried out by Engels (1983) and Newstrom (1986) on the variation in cultivated types contained in the collections revealed the following:

The variation registered for characteristics referring to size and shape of the fruit is apparently continuous.

In most cases, the descriptors with no apparent relation to the size of the fruit were independent among themselves, and no significant differences were found in the diversity of samples from Central American countries, nor between them and those of Mexico.

Consequently, it is very difficult to catalogue the variation of chayote as cultivars and it has been decided, therefore, to refer to them as landraces.

Another outstanding aspect of the information available in chayote germplasm catalogues is the marked difference between the diversity handled by traditional farmers and that which is produced for commercial reasons. For example, in the vast majority of cases, samples of fruit collected from traditional market gardens vary in size, colour and taste, and generally they are partially or entirely covered with spines. Commercial production, however, has to conform to the demands or quality norms imposed by export markets (FAO 1982, in Flores 1989). According to these, the fruit should be relatively uniform in size and other external morphological features (pyriform fruit, light green or white, smooth or unarmed, approximately 15 cm long and weighing approximately 450 g), in presentation (no signs of premature germination, physical damage or marks produced by pathogens) and in texture and flesh flavour (soft and pleasant) (Fig. 6).

Taking these commercial restraints into account, and the fact that little or nothing is known about the heredity of many morphological features of chayote fruit, we can expect that it will be difficult to use traditional market garden cultivated types of chayote in improvement programmes which breed for commercialization of chayote. How, then, can the variation which exists in traditionally cultivated chayote be exploited? Or, in other words, what is the justification for conserving and studying it?

Although the resistance of chayote germplasm accessions to abiotic and biotic environmental variables, such as pests and disease, has never been determined, it can be assumed that there must be diversity with regard to these factors. Data provided by Cruz-León and Querol (1985) on plant behaviour during a yearly cycle (Table 4) clearly showed there is diversity in how early plants produce fruit (number of days to harvest) and how productive chayote plants are (number of fruits per plant). Some types produced fruit from 102 to 331 days after sowing, with production varying from 374 to 521 fruits on plants with medium-duration fruit formation (208-239 days) and up to 402 fruits for more precocious plants (102 days). Further analysis of this variation may make it possible for some of these types to be used for improving commercial chayote yields.

In spite of failures experienced to date in the *ex situ* conservation of *Sechium* genetic resources, interest in the subject has not been completely lost. In Costa Rica, for example, *in vitro* conservation was another method which was explored to see if there was any way it could be used as an alternative to field genebank collections (Alvarenga and Villalobos 1988; Alvarenga 1990). Although the preliminary results obtained are still at experimental level, they appear to be promising. These results showed that it is possible to stop the growth of explants by submitting them to individual and / or combined treatment using osmotic stress (4-8% sucrose), low temperature (16-22°C) or acetylsalicylate acid (10^{-9} up to 10^{-3}M). The most effective combinations, which neither damaged nor caused morphological change in the explants, were osmotic pressure at 6% sucrose and a temperature of 18°C.

In 1992, a new chayote germplasm collection was set up in the Ujarras Valley in Costa Rica. This is an extensive conservation initiative based on the Costa Rican *Sechium* Germplasm Bank Project which was set up by private and governmental institutions from Costa Rica and Spain (National University of Costa Rica, Coopechayote R.L. and the Spanish International Cooperation Agency) with the support of the Costa Rican National Commission for Plant Genetic Resources (Brenes 1996). The project has been well received and it has recently been joined by other institutions from Costa Rica such as The Association of Sustainable Agricultural Producers of the Ujarras Valley (in place of Coopechayote R.L.), the University of Costa Rica and the Ministry of Agriculture and Poultry.

The main objective of this project is not just to set up a field genebank collection of cultivated chayotes in Costa Rica, but also to form a world reservoir of genetic resources of the genus *Sechium*. One of the essential parts of the project will be to collect systematically germplasm for the entire genus. This will be conserved initially as field genebank collections and a database consisting mainly of information related to characterization, conservation, improvement and use will be established. Additionally, it is hoped that the project will encourage the *in situ* conservation of wild species, the development of efficient methods for the phytosanitary handling of collections as well as the study of seed germination of wild and cultivated species in the genus and the vegetative propagation of wild species and of the other cultivated species *S. tacaco*. Medium-term aims of the project include furthering studies on the biochemical characterization of the collections, carrying out the research needed to be able to set up an *in vitro* collection representative of the main field genebank collection, and identifying promising material for the genetic improvement of the two cultivated species.

The achievements to date of this project seem to indicate that the above strategies might soon give satisfactory results. According to one of the participants in the project (A. Brenes, pers. comm.), during 1995 a total of 95 accessions for *S. edule* (91) and *S. tacaco* (4) fruit were registered in the bank. Encouraging the *in situ* conservation of wild species is also underway, mostly through the contact with research institutions located in areas where populations of wild *Sechium* are known to occur. On the other hand, a programme is being carried out to increase public awareness of the importance of conserving *S. tacaco* genetic resources. Pamphlets have been distributed with information on the project and inviting interested members of the public to adopt and monitor *S. tacaco* plants. At the same time, academic support activities have been developed for people participating or who wish to participate in the project. Such activities include compiling a systematic bibliography on the *Sechium* genus (Saborío *et al.* 1994) and drawing up a reference catalogue with all the available data on diseases which attack chayote crops (Rivera and Brenes 1996).

Also in 1992, another chayote genebank was set up in Nepal, as a result of a chayote breeding programme funded by the US Agency for International Development USAID), and led by Moha Dutta Sharma of the Institute of Agriculture and Animal Sciences (IAAS), Tribhuvan University (Sharma *et al.* 1995). The three main objectives of this project are to:

- evaluate germplasm collected from Mexico, Costa Rica and India, in order to select plants demonstrating adaptability to annual cultivation (early maturity, compact habit), marketable qualities (excellent flavour, appropriate size and texture), and desirable agronomic characters (high yield, resistance to drought and heat)
- develop cultural practices to optimize fruit, tuber, or shoot production in tropical, subtropical and temperate regions of Nepal
- to disseminate the improved lines and agronomic information resulting from the project to subsistence and commercial growers, research scientists and government agencies in Nepal and abroad.

Currently, 200 accessions from Mexico, Costa Rica, South India and Nepal are growing in this genebank and they have been evaluated and selected.

According to Sharma *et al.* (1995), the Nepalese genebank has several advantages for long-term conservation. The most important one is that the collection contains only chayote, so there is no competition from other major crops. On the other hand, since chayote is not native to Nepal, the pests and diseases might be much rarer than in its native regions. Another advantage is the association of the genebank with an active breeding programme conducted by experienced chayote specialists and a team of other scientists (entomologists, plant pathologists and horticulturists) from Nepal research centres.

The aims of these two new chayote germplasm conservation projects may seem rather ambitious, but they are certainly initiatives with interesting and promising features. In Nepal, for example, is very advantageous that the genebank is only devoted to chayote germplasm and its close relationships with a local breeding programme is very important. As for Costa Rica, one of its most interesting features is the fact that groups of chayote producers together with government, teaching and research institutions are all involved in this scientific undertaking. Another is that all wild species of *Sechium* are being taken into account, as are strategies for their conservation. It is hoped that these activities will be successful in the medium term and that all the participating institutions will continue to support this working group as they have done up to now.

7 Breeding

The above information makes clear that the commercial production of chayote is affected by pests and diseases, as well as by the need to mantain the fruit quality. Accordingly, it is necessary to develop a breeding programme that takes into consideration these two aspects. However, so far this kind of programme has not been systematically developed, and only written proposals to this respect have been issued. Thus, for example, Newstrom (1986) proposed the development of two different breeding lines: the first focused in producing unflavoured fruits for industrial purposes, and the other on producing tasty fruits for vegetable use. On the other hand, as an alternative to the development, improvement and production of new phenotypes, she also proposed to collect and evaluate a comprehensive sample of these phenotypes in Mexico and Central America. An additional point of view to this respect has been pointed out by Aung *et al.* (1990), who suggested the possibility of selecting chayotes on the basis of root characters such as length and starch content, which might be related to different types of chayotes as well as to their growing conditions.

The author considers that the simultaneous development of all these breeding strategies is very important. Additionally, he believes that it is also important to evaluate wild species for some of the objectives mentioned above, especially those related to disease resistance. Fortunately, as has been mentioned before, most of these factors have already been included in the objectives and workplans of the two new chayote genebanks.

8 Areas of production and consumption

Chayote is widely cultivated throughout the Americas where, as mentioned above, it was cultivated by the Aztecs long before the Spanish arrived. It is thought that its presence in the northern part of Central America is the result of Aztec and Mayan influence in this region, and it is known that the Spanish introduced it into Costa Rica (Bukasov 1981). The chayote is known to have been introduced into South America during the 18th and 19th centuries (Bukasov 1981; Newstrom 1986, 1991). It is possible that it was introduced into the Caribbean prior to this since the first formal mention in the literature was by Browne (1756) who points out that, by that time, this species was widely cultivated throughout Jamaica. During this same period, chayote was introduced into Europe and, from there, it was taken to Africa, Asia and Australia. However, it was not introduced into the United States until the end of the 19th century (Cook 1901; Flores 1989; Newstrom 1991).

Table 6. Chayote production in different states of Mexico, 1991-93.

State	Year	Area (ha)	Yield by area (t/ha)	Total production (t)
Baja California	1991	8	10	80
	1993	10	7	56
Guanajuato	1991	37	0	0
	1993	n.a.	n.a.	n.a.
Jalisco	1991	547	27.5	8377
	1993	300	37.7	11314
Edo. de México	1991	69	32.0	1140
	1993	68	12.0	408
Michoacán	1991	94	20.0	1880
	1993	112	19.0	2128
San Luis Potosí	1991	15	24.0	360
	1993	15	18.0	270
Sinaloa	1991	9	20.0	180
	1993	n.a.	n.a.	n.a.
Veracruz	1991	592	98.40	34 142
	1993	1061	116.86	65 320
Total	1991	1371		46439
	1993	1566		79496

n.a. = no information available.
Source: Secretaría de Agricultura y Recursos Hidráulicos 1991, 1993.

Currently, chayote is cultivated in some parts of the United States such as California, Louisiana and southern Florida (Newstrom 1991), and in the Old World it is cultivated at least in India (Chakravarty 1990; Kabitarani and Bhagirath 1991), Nepal (Sharma *et al.* 1995), China (Yang and Walters 1992; Cheng *et al.* 1995), Papua New Guinea (Bradbury *et al.* 1985), Southeast Asia, Taiwan (Chou *et al.* 1976; Aung *et al.* 1990; Engels and Jeffrey 1993) and some European countries such as Italy (Perrino and Hammer 1985) and ex-Yugoslavia (Dubravec 1986). It is, however, possible that it is not entirely established as a crop in all these regions since, as we shall see later, the United States as well as some European and Asian countries currently import chayote from Latin America.

Although detailed figures do not exist, it is known that in 1978 chayote was the fifth most important commercial vegetable crop in Brazil, when 170 000 t were produced. During this period, 12 000 t were produced in Mexico (Engels and Jeffrey 1993), where, in 1991, a total of 1371 ha were used to produce 46 439 t of chayote. In 1993, these figures were increased considerably to 1566 ha which produced 79 496 t (Secretaría de Agricultura y Recursos Hidráulicos 1991, 1993; Table 6), with the highest production coming from the States of Veracruz, Jalisco and Michoacan. According to Núñez (1994), in 1991 Costa Rica produced 16 307 t from only 220 ha.

In spite of these figures, the impact of each of these countries on the international market has been very different. Costa Rica is clearly the leading trader and exporter of this crop and exports mainly to the United States and also to other countries in the Americas (Canada, Colombia, Guatemala, Netherlands Antilles, Nicaragua and Honduras among others) and elsewhere (France, Germany, Great Britain, the Netherlands, Belgium, Luxembourg and Japan) (Zuñiga 1986). Recent data (Table 7) show that during the 1990s Costa Rica has maintained this lead and is still the main exporter of chayotes to the United States, with Mexico in second place. Exports from other countries such as Peru, Dominican Republic and Brazil, have been sporadic and in far smaller quantities. Figure 11 shows the distribution of the main centres of chayote production in Mexico.

Table 7. US chayote imports, 1992-95.

Imported from	Unit	1992	1993	1994	1995*
Mexico	kg	1 968 920	1 453 813	1 982 338	1 473 774
	US$	1 262 840	1 183 995	1 490 883	1 013 000
Costa Rica	kg	15 532 399	12 186 630	12 697 314	9 816 238
	US$	6 677 874	7 457 527	8 658 237	5 118 000
Dominican Republic	kg			23 030	
	US$			9000	
Peru	kg			4704	
	US$			8000	
Brazil	kg			5250	
	US$			5000	

* The data for 1995 only include information for January-August, and were obtained from the electronic information

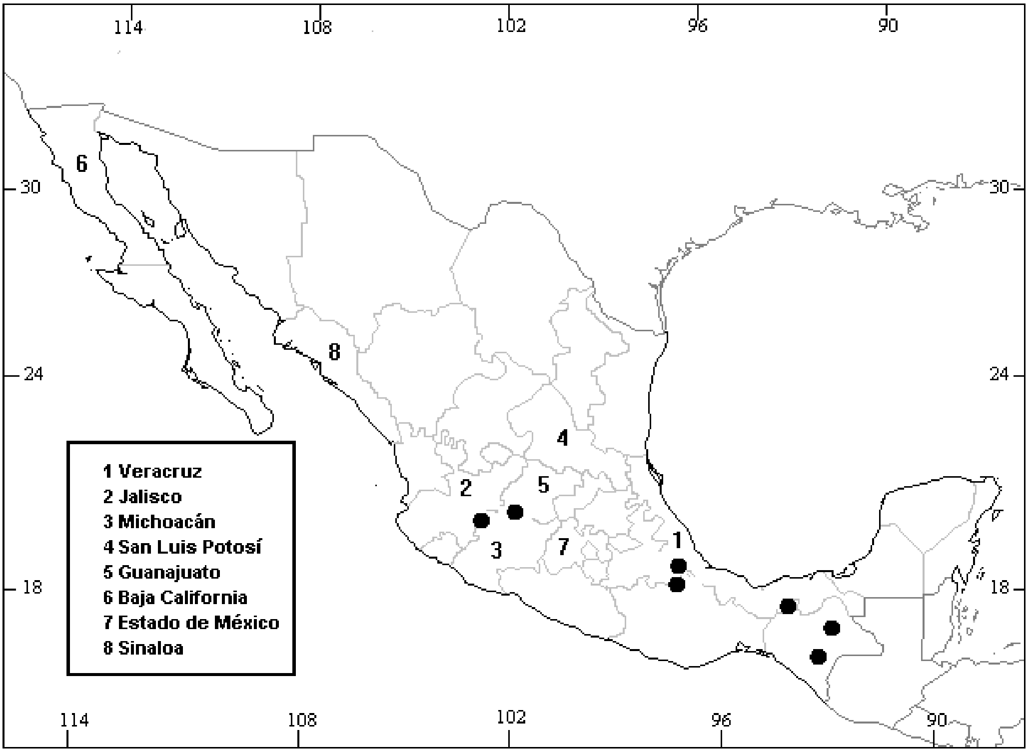

Fig. 11. Important production states of chayote in Mexico, and sites where most of its germplasm samples have been collected.

systems of Trad Stat and National Trade Bank.

The success of Costa Rica in this field is especially outstanding in view of the fact that export activities for this crop were only initiated in the 1960s (Flores 1989; Núñez 1994). The main part of Costa Rica currently used to produce chayote for export is Ujarras, located in the Paraiso Canton, while other areas such as Alajuelita and San Ramón de Alajuela are used mainly to produce for the home market (Vargas 1991).

According to a study carried out within the main area of production of chayote in Costa Rica (Zuñiga 1986), during the last decade chayote producers of this country obtained 6.85 colones (approximately US$0.08 at that time) per kilogram of fruits produced and delivered to the packers. The same author points out that the main input carried out by these producers were the labour costs (principally harvesting, fruit selection, irrigation) – 29.8 %; field materials (fertilizers and fungicides) – 21.9 %, and indirect expenses (transportation and field renting) – 22.08 %. In spite of these data, one of the conclusions of Zuñiga's work was that, at least at that time, chayote production was highly profitable for the producers who obtained on average between 93% and 133% of earnings. Currently this situation might be different; however, no updated information is available from Costa Rica or Mexico for comparison.

9 Ecology

Chayote is traditionally cultivated in empty patches, backyards and market gardens as well as in plantations for commercial purposes. It is a medium- to high-altitude crop (300-2000 m asl), it requires a high relative humidity (80-85%), well-distributed annual precipitation of at least 1500-2000 mm and 12 hours daylight to initiate flowering (Flores 1989; Vargas 1991; Engels and Jeffrey 1993). The most suitable average temperature is 13-21°C. Temperatures of less than 13°C damage small or unripe fruit while those above 28°C favour excessive growth and the falling of flowers and unripe fruit, all of which reduces production (Vargas 1991). Flores (1989) points out that chayotes for export grow best on sites located at 1000-1200 m asl.

While topography and stoniness do not seem to be important factors for the cultivation of chayotes, other soil factors do. Vargas (1991) points out that productivity is greater in deep soil with plenty of organic matter but is affected negatively by clay or sandy soils which retain moisture and encourage the development of diseases, especially those caused by fungi.

The above indicates that chayote is highly susceptible to frosts, droughts and excessive humidity, as well as to certain soil factors. However, in spite of this, herbarium and germplasm records as well as field observations show that there is a wide geographical/altitudinal distribution for most of the genetic diversity of this crop. In fact, according to Aung *et al.* (1990), it is possible to grow chayote in temperate regions during summer and early fall months, although the fruits should be presprouted and the plantlets grown under greenhouse conditions before setting them outdoors when danger of frost has passed.

10 Agronomy

Propagation and planting Although this will vary according to the state of the site, it will normally consist of clearing weeds from an area of approximately 2 m in diameter around the point where the seed or fruits are to be planted. With sloping sites, farm workers in Costa Rica prepare small, individual terraces to prevent soil erosion (Zuñiga 1986). On commercial plantations, lime is often applied as are nematicides and fertilizers rich in nitrogen and organic matter (Zuñiga 1986; Flores 1989; Vargas 1991; Núñez 1994).

The most common and efficient way of propagating chayote is to use the seeds/fruits and the most common way of planting consists of planting one or more complete fruits once the seedling has sprouted. At least in some places in Mexico, the seed is removed from the fruit and placed in a flower pot or some other place where the young plants can be carefully tended before being transplanted to where they will grow (Castrejón and Lira 1992).

Propagation by seeds/fruits is also used in commercial plantations, although vegetative propagation by planting basal shoots is sometimes used as well. This latter method is fairly successful but it requires additional investment in order to ensure that the sprouts grow adequately (installation of controlled humidity chamber, use of hormones, areas for reseeding and monitoring, etc.) (Valverde *et al.* 1986; Zuñiga1986). It has been observed that the use of this method increases plant loss, favours the spread of disease and can even lead to decreased plant productivity (Núñez 1994; Valverde *et al.* 1986).

In areas where chayote is traditionally produced, the planting site is prepared in advance. A sufficiently large hole (usually filled with organic manure) is dug to enable the roots to grow to their full extent without damage. A frame of branches, wood or some other kind of material is often made nearby so that the plant has somewhere to climb. Seeding is often near a tree for this reason. In commercial plantations a trellis system is established consisting of wooden poles and wires (Fig. 12). During the first weeks of plant development, care is relatively intense (watering, fertilizing, etc.) although attention to the root (protecting it from physical damage and adding fertilizer) is considered to be of great importance throughout the life cycle of the plant.

The number of plants and/or types of chayote which can be cultivated in a traditional market garden varies considerably. Much will depend on the size of the site and seed availability. In some parts of Mexico, for example, the author has seen home gardens where usually only one plant is grown, always with the same type of fruit morphology, while others with up to five plants grow simultaneously and all produce fruit with different morphology. On commercial plantations, of course, this does not happen. The distance between each planting point varies from 6 to 10 m and the number of seeds/fruits planted is from 1 to 4 (Zuñiga 1986). According to Zuñiga (1986), the planting density is an aspect that must be further investigated. An inaccurate choice of this density might require either the reduction in the

Fig. 12. Trellis system in commercial plantation.

number of plants or the addition of new ones, which in both cases will involve additional costs in labour.

Planting of chayote can take place at any time during the year, although it is often done at the beginning of the rainy season or even during the months of highest precipitation. This fact is important, mainly because during the first stages of its growth, the plant develops a very dense foliage which causes a vast loss of water by means of evapotranspiration (Zuñiga 1986). The duration of the productive cycle of the plant varies considerably for phenotypes produced in traditional agriculture areas. Plants can be found which have been producing continuously for long periods, sometimes for 8 years or even more (Lira 1995a, 1995b). On commercial plantations, however, the life cycle of the plants is from 1 to 3 years. The plants are then removed and replaced to help prevent the spread of disease. Moreover, it has been observed that after the first year of production, the plants begin to lose their strength and productivity is reduced (Zuñiga 1986).

Care of chayote plants generally includes cleaning or weeding, the applicarion of pesticides and herbicides, and irrigation (Zuñiga 1986; Flores 1989; Vargas 1991; Nuñez 1994). All of these activities are carried out more intensely and systematically on commercial plantations. Cleaning or weeding is usually carried out manually or with the help of herbicides during the growing period (Vargas 1991). Although fertilizing with complete formula products (15-15-15, 12-24-24) usually does not take place until 2 weeks after seeding, Vargas (1991) points out that it is highly recommendable for phosphorus-rich fertilizers to be applied in the holes where seeding is to take place. She also points out that irrigation during the dry season is of vital importance given the high transpiration rate of chayote plants and the fact that roots are superficial. She suggests sprinkling as the best method since this helps reduce infestation by mites known as 'arañitas rojas' (*Tetranychus urticae* Koch), one of the worst pests for chayote.

Harvesting One plant can produce even more than 300 fruits per year. Yields of 22-28 t/ha have been reported from commercial plantations (Engels and Jeffrey 1993). Chayote fruits are harvested manually as often as required depending, obviously, on the productivity of the plant. On commercial plantations, however, given the uniformity of the materials used, harvesting is programmed and much more systematic. It involves the collection of fruits 2-4 days per week during the production time, as well as the selection and classification of fruits for export and home markets. In general, the most common strategy is to devote 1 day a week to harvest fruits for exportation and the remaining days to harvest the fruits for local markets. Once the fruits have been collected and selected, they are put in wooden boxes and sent to the packers (Fig. 13). There, a second selection process takes place after which the fruits are packed in cardboard boxes and plastic bags with antitranspirants and fungicides (Figs. 14, 15); these are then sent in refrigerated containers (Zuñiga 1986; Flores 1989).

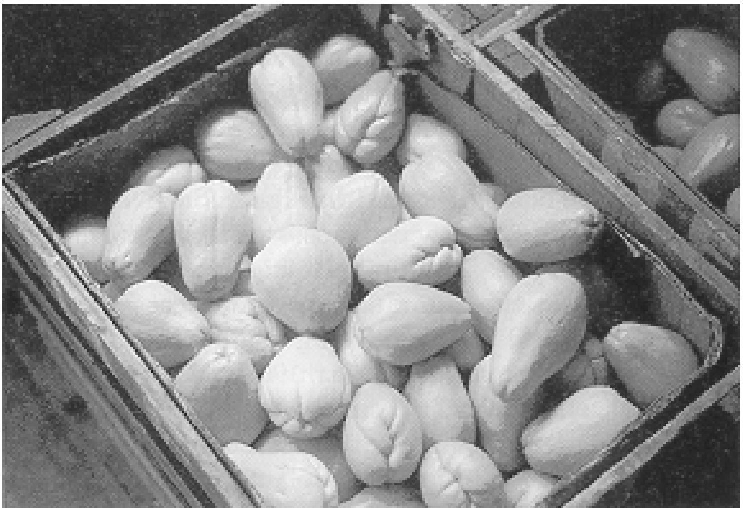

Fig. 13. Boxes to be sent to packers.

Fig. 14. Selection process.

Fig. 15. Fruits in cardboard boxes ready for shipping.

The harvesting of the tuberous parts of the roots is much more complicated and has to be done with great care to avoid damaging the plant. According to Cruz-León and López (1989), tuberization takes place during the cold period and can initiate during the first year of the plant's life. Apparently, as with the leaves, the roots are renewed each year since, once new ones are produced, the previous ones start to lose turgidity and putrefaction begins.

Postharvesting How the fruits are taken care of when harvested is of paramount importance from a commercial perspective, particularly in view of the fact that chayotes stored at ambient temperature spoil completely after 30 days (Vargas 1991). Tests carried out to date to find the most efficient ways of protecting fruit packed for export show that the use of plastic bags greatly reduces loss of humidity although it increases the incidence of pathogens such as *Mycovellosiella cucurbiticola*. This, however, can be controlled through the use of antitranspirants, which also reduce chilling injury (Alvarado *et al.* 1989).

In addition, it has been suggested that tests should be carried out to determine the optimum conditions of temperature and humidity in cold chambers. Tests at temperatures of 13-14°C and 80-90 % humidity have shown that fruit begins to germinate after 15 days, drops constantly in weight and pathogens develop (Alvarado *et al.* 1989; Valverde *et al.* 1986).

11 Pests and diseases

Much of the effort to find ways of improving crops commercially is dedicated to the search for new pest- and disease-resistant genotypes. However, paradoxically, pests and diseases often increase as ways of improving production and yield are implemented. The chayote is no exception. Many of the practices used in commercial crops (genetic homogeneity of seed material, sexual and vegetative methods of propagation, and the closeness of plantations) have produced a series of pests and diseases in this crop both in its area of origin and in other parts of the world (Rivera and Brenes 1996).

As mentioned before, one of the most worst pests is the mite known as 'arañita roja' (*Tetranychus urticae*) which frequently appears during the dry season and produces yellowing of the leaves and clear scabs on the fruit. It is thought that this pest

Table 8. Important and common pests and diseases of cultivated chayote.

Spanish common name	Causal agent or vector	Affected organs	Symptomatology
Roña o Sarna	*Phoma cucurbitacearum* Fungus	Fruits	Clear and brown necrotic areas, appearing corky and depressed
Vejiga o Salpullido	*Mycovellosiella cucurbiticola, M. lantanae* Fungi	Fruits	Watery pustules
Pudrición Chocolate	*Colletotrichum* spp. Fungi	Fruits	Concave lesions with defined borders, with a central gelatinous orange spot
Estrella Negra	*Venturia cucumeris* Fungus	Leaves	Spots on leaf nerves
Mildiú Pulverulento	*Erysiphe cichoracearum* Fungus	Leaves	Leaf spots
Mancha de Cercospora	*Cercospora cucurbitae* Fungus	Leaves	Leaf spots
Pudrición de Corona	Pathogen associations: (*Ascochyta phaseolorum, Fusarium* spp., *Colletotrichum* spp. and *Macrophomina* spp.) Fungi	Fruits	Blackish lesion of the fruit peduncle, that may advance to other parts of the fruit; mainly present in the post-harvest period

helps transmit the fruit disease known as ‘sarna’ or ‘roña’ (scabies / mange) since the scabs increase as the plants become more infested (Vargas 1991). Secondary pests include: Lepidoptera such as *Diaphania hyalinata* L. and *D. nitidalis* (Stoll), which perforate unripe fruit, opening up ways of access for fungal and / or bacterial diseases; Hemiptera such as *Aphis* spp. and *Bemisia tabaci* (Genn), which suck the leaves, fruit peduncles and occasionally the fruit, causing dark blemishes which make the fruit unmarketable; Coleoptera such as some of the species of the *Phyllophaga* and *Diabrotica* genera, which mainly attack the fruit but also the seedling (Vargas 1991).

As shown in Table 8, a wide range of pests and diseases attacks chayote. Most of these are caused by fungi although some are caused by nematodes and insects. These diseases are of great importance since they can attack one or more parts of the plant at any time during its development, including after harvest (Pereira and Zagatto 1973;

Spanish common name	Causal agent or vector	Affected organs	Symptomatology
Peca Blanca	*Ascochyta phaseolorum* Fungus	Leaves and fruits	White circular depressed lesions, with black prints and a deep green border; can be associated with *Pseudomonas*, and turn wet with a brown halo
Chino del Chayote	*Empoasca solana* and an unidentified species of subfamily Thyphiocybinae insects	Whole plant	Yellowing of whole plant, growth reduction through internode shortening, axillary bud proliferation, small curled, deformed leaves and yellowing, reduction in size and mummification of fruit
Jobotos	*Phyllophaga* sp. Insect	Seedlings	Lesions caused by herbivores
Unknown	*Meloidogyne incognita* *Helicotylenchus* sp. Nematodes	Roots	Root rotting
Unknown	*Helithosporium sechium* Fungus	Leaves	Leaf spots
Unknown	*Fusarium oxysporum* Fungus	Leaves and stems	Leaf yellowing and stem withering; common in drought period

Koch 1974; Chou *et al.* 1976; Kitajima *et al.* 1981; Bala and Hosein 1986; Nava del Castillo 1986; Vásquez *et al.* 1986; Flores 1989; Vargas 1991; Rivera and Brenes 1996). These studies show that fungi, which are known to be associated with approximately 33 diseases, are among the most important pathogens and include *Ascochyta phaseolorum* and various species of *Fusarium, Macrophomina* and *Colletotrichum*. Also, harvested fruits can be affected by one or more of these pathogens.

The most important nematodes are *Meloidogyne incognita* and *Helicotylenchus* sp. which cause rotting of the roots. Among insects, we find the *Empoasca solana* which is the vector of a disease known as 'chino del chayote' (chayote curl). Rivera and Brenes (1996) mention several other diseases including some viral diseases such as the Tomato Spotted Wilt Virus or the 'Vira Cabeça do Tomateiro' and 'Mosaico', both of which to date apparently have only been found in Brazilian plantations.

Since the fruits are made unmarketable by many of these and other diseases, it is of vital importance for the commercial development of the crop that more effort is made to control such diseases (Sáenz and Valverde 1986). Several chemical products are available for controlling pests and diseases. Alternately, they can be controlled manually by removing the damaged part of the plants, but this process is long and tedious. Another strategy used is the rotation of crops that frequently are associated with chayote plantations.

12 Limitations of the crop, research needs and prospects

A first point revealed by the information compiled in this work is that farmers wanting to cultivate this crop commercially have to deal with pests and diseases, not only at different stages in plant development, but also after harvesting. However, as has been pointed out, much information is lacking on the genetic potential of both the wild related species and the different landraces of the crop. One of the results of this is that pest and disease control programmes have never tried using non-commercial cultivated types or some of the wild species to breed for resistance. Neither has any kind of biological control ever been used to reduce pest populations.

This clearly shows that one of the first steps which needs to be taken is that of setting up an evaluation and selection programme in order to determine which materials can be used for such improvements. It is also important that we learn more about the taxonomic relationships between the species of *Sechium*, as well as many other biological aspects of the genus. However, one vital prerequisite for this is the access to representative collections of the genetic diversity of all the species in the genus. Unfortunately, this has not been possible so far, mainly because of lack of support for maintenance and handling of such collections.

Another problem is related to the knowledge about the uses of the plant. In spite of the fact that *S. edule* is a species with multiple and integral uses (several parts of the plant are used for different purposes), most of these are unknown outside farming or rural communities. In addition, the remarkable diversity of fruits produced by traditional methods in rural areas of Latin America and particularly southern Mexico and Central America, is of limited commercial value because the market demands morphologically uniform fruits.

What is obvious from the above is that there is a lack of wide interest in a crop which, in one way or another, currently brings economic benefits to only a small sector of the population that cultivates it for commercial reasons. It is also fair to say that the genetic diversity of this crop is currently more or less being saved by traditional agriculture. However, the difference in income obtained by commercial and traditional farmers is putting this at risk. If traditional farmers abandon their traditional production methods or decide to produce other crops for commercial reasons, then the genetic diversity which is still to be found in this crop may be lost.

Some of the steps needed to solve the problems mentioned here are currently being taken by the Costa Rican and Nepalese projects, especially with regard to conservation and evaluation of cultivated and wild material of the entire genus *Sechium*. Government authorities, research and teaching institutions, commercial producers and the public in general are all being involved in these and other related tasks. However, since the results of this project will not be seen for some time, complementary or similar strategies could be undertaken by other countries in areas where the greatest concentration of chayote diversity exists.

Such strategies could include, for example, the drawing up of cooperative agreements among Mexico and the Central American countries for bringing together new germplasm collections. In addition, attempts could be made to open up markets for the local varieties of chayote from these areas, not just for food but also for the use of the fruit pulp in industrial processes. This would mean that fruits would not have to conform to export quality requirements. Equally important is the continuation of research on the medicinal potential and other aspects of chayote. There also has to be a more systematic way of marketing products and / or subproducts which can be obtained from cultivated chayote and even perhaps from some wild relatives. It would appear, for example, that the roots of *S. compositum* could be used as a source of saponins since they are used as a soap substitute in several places in Mexico and Guatemala.

With regard to wild species, we need to carry out more studies on how they are related to cultivated chayote and their presumed potential as genetic resources. In this way we can justify their conservation. The limited distribution of all these plants and the growing destruction of their habitats mean that we have to accelerate work in this field. Similarly, we need to know more about how well they can be conserved *ex situ* and *in situ*. In the case of chayote, this really should be done in Mexico and the neighbouring areas of Guatemala since this is where its presumably closest wild relatives thrive.

It may be that much of the above is difficult to undertake, especially since much of it involves economic and political resolutions, and support from several countries. However, as scientific knowledge of this crop grows, it will no doubt provide firmer bases which will justify asking for such support. This has recently been the case for cassava and rice. Different strategies are currently being implemented for both these crops in an attempt to conserve their wild and cultivated genetic resources (Vaughan and Chang 1992; IPGRI / CIAT 1994).

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Appendix I. Research contacts, centres of crop research, breeding and plant genetic resources of chayote.

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