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Introduction and Domestication of Rare and Wild Fruit and Nut Trees for Desert Areas*

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INTRODUCTION

The range of crops that can be grown commercially in hot desert regions is very limited. This is specially true for orchard crops. The purpose of our research program is to develop new crops for hot desert areas through introduction and domestication. Our approach is based on perennial plants from two sources: wild plant species from arid and semiarid areas, yielding nutritious fruits or nuts eaten by the local people (Wehymeyer 1966, Felger and Moser 1976, Biesele et al. 1979, Felger 1980, Fox and Norwood-Young 1982, Taylor 1986); and rare fruits that can be obtained in local markets or from growers of rare fruits. Israel's Negev desert, with its broad spectrum of climatic conditions and types of soil and water, is an appropriate site for such a project. We have set out to exploit the Negev's variation to test the suitability of a number of plant candidates for introduction and domestication in desert areas. This is our first report on the project, and summarizes four years of work starting from 1984. We will describe our activities in general and give some details regarding six of our plant candidates.

METHODOLOGY

Suitable plant candidates, i.e., wild or semi-domesticated perennials yielding tasty, nutritious fruits or nuts as well as fruit trees not commonly cultivated in developed countries, were selected on the basis of information collected from rare fruit growers and investigators. The common and botanical names and families of the plant candidates are listed in Table 1. With the exception of *Opuntia ficus-indica* and *Ziziphus mauritiana*, which were introduced as cuttings and grafted plants, respectively, all the plant material was obtained from seeds collected in the wild or obtained from growers of rare fruits.

Seeds were germinated and plants established under quarantine conditions, then transferred to a nursery. Introduction orchards were established throughout the Negev desert (Fig. 1). Each of the introduction orchards has distinct climate and water quality characteristics (Tables 2–4). To eliminate the effect of random local conditions each species was planted in three separate blocks at each site. Five to ten plants were used for each species per block.

All orchards are equipped with drip irrigation systems. Each tree is supplied with a 2-liter/hour dripper. When the canopy has developed either the dripper is replaced with one of larger capacity, or additional drippers are added. Fertilization with NPK is given via the irrigation system. Sequestrene 134 is applied to correct iron deficiency symptoms. All irrigation and fertilization regimes were adapted from the recommendations of the Extension Service for mango trees grown in the Negev area (Frenkel and Zohar 1987). The following operations relevant for plant establishment are being carried out at all locations: growth measurements; phenological observations; climate, soil, water, and mineral analyses.

At the next stage, fruit and nut yields and quality will be determined, followed by clonal propagation of the selected clones and rootstocks.

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Table 1. List of candidate species.

Botanical Name	Common Name	Family
Fruits		
Casimiroa edulis	White sapota	Rutaceae
Crytocarpa edulis	Ciruelo	Anacardiaceae
Diospyros digyna	Black sapota	Ebenaceae
Dovyalis caffra	Kei apple	Flacourtiaceae
Hylocereus undatus	Pitaya	Cactaceae
Inga vera	Ice cream bean	Mimosaceae
Manilkara zapota	Sapodilla	Sapotaceae
Mimusops angel	Angel	Sapotaceae
Opuntia ficus-indica	Prickly pear	Cactaceae
Pachycereus pringlei	Cardon	Cactaceae
Santalum acuminatum	Quandong	Santalaceae
Sclerocarya birrea subsp. *caffra*	Morula (Marula)	Anacardiaceae
Stenocereus gummosus	Pitahaya agria	Cactaceae
Stenocereus thurberi	Pitahaya dulce	Cactaceae
Strychnos cocculoides	Monkey orange	Loganiaceae
Vangueria infausta	Mmilo	Rubiaceae
Ziziphus mauritiana	Ber (Indian jujube)	Rhamnaceae
Nuts		
Bombax glabra	Malabar	Bombacaceae
Cordeauxia edulis	Yehib	Caesalpiniaceae
Ricinodendron rautanenii	Mongongo (Manketti)	Euphorbiaceae

Table 2. Climatic data for the four introduction sites.

Parameter	Qetura	Neot Hakikar	Besor	Ramat Negev
Mean daily temperature (°C)				
Hottest month (August)	30–32	32–34	26–28	26–28
Coldest month (January)	14–16	14–16	12–14	8–10
Annual number of days with temperature of:				
35°C or more	125–150	126–150	0–10	11–25
10°C or less	1–25	1–25	76–100	126–150
Average pan evaporation rate (mm/day)				
Hottest month	15	14	8	10
Coldest month	4	5	3	3
Annual rainfall (mm)	<40	<40	200	90

Table 3. Water quality at the four introduction sites.

				Ramat-Negev*	
Parameter	Qetura	Neot Hakikar	Besor	Fresh water	Brackish water
EC (dS/m)	3.2±0.6	3.7±0.2	0.9	0.9	6.1±0.1
pH	7.7±0.3	7.6±0.2	7.4±0.1	7.5±0.1	7.2±0.3
ion content (mg l)					
Na^+	259±90	300±10	95±7	95±7	1080±5
Ca^{++}	262±9	208±11	51±1	45±2	227±9
Mg^{++}	103±13	133±3	29±4	29±4	83±7
Cl^-	588±52	885±22	290±25	240	1800±5
SO_4^{--}	823±228	360±43	49±2	47±2	490±5

Values in the Table are means ±SD of samples taken throughout the last year.
*At this location we are in the process of establishing plants for comparison of fresh and saline water irrigation.

Table 4. Soil properties at the four introduction sites.

Parameter*	Qetura	Neot Hakikar	Besor	Ramat Negev
Texture	sandy loam	sandy loam	sandy loam	loam
Conductivity (dS/m at 25°C)	0.63–3.39	1.34–6.13	0.6–2.1	0.7–2.3
pH	7.4–7.7	7.3–7.7	7.7–8.3	7.9–8.5
Total $CaCO_3$ (%)	6–10	14–32	2–12	8–27

*Soil was analyzed to depth of 120 cm.

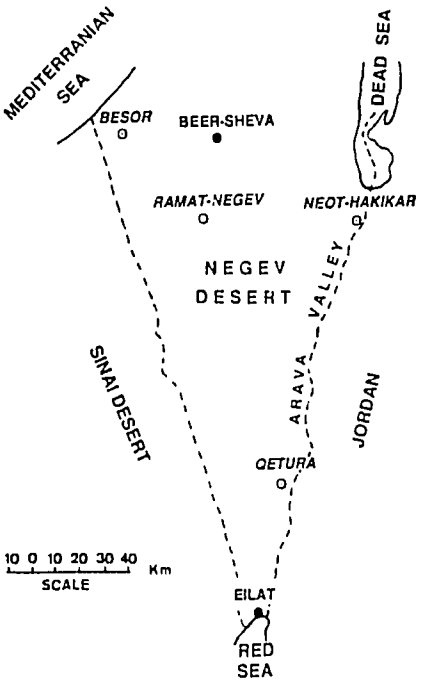

Figure 1. Site of experimental orchards established in the Negev desert.

PROMISING SPECIES

Cordeauxia edulis

Yehib is an evergreen shrub native to arid zones on the borders of Somalia and Ethiopia. The plant produces pods usually containing a single seed weighing 2–3 g and rich in starch and sugars. The seed is tasty and is used by nomads as a staple food. It is also sold in local markets. The Yehib has been described as a drought tolerant plant and is an endangered species (Miege and Miege 1979, National Research Council 1979).

Seeds germinated well, and seedlings grew under quarantine conditions and then in the nursery. Upon transfer to the various locations growth was inhibited, followed in many cases by death. With the exception of a few survivors at Qetura, the yehib plants did not become established in most of the orchards. Growth of the survivors occurred from May until October but was very slow both in the nursery and in the orchard (Fig. 2 and 3). Yellowing of leaves was common in many plants, generally followed by death. The survivors also showed some yellowing of leaves; this phenomenon was particularly marked in mid-summer, when temperatures can reach up to 48°C, but it was also observed in winter.

Ricinodendron rautanenii

Mongongo is a large, dioecious, deciduous tree which grows in the wild on sandy soils between latitudes 15 and 21°S in southern Africa. The fruit of the tree has a thin edible flesh and a pleasant-tasting kernel contained in a hard-walled stone. The kernel weighing about 1.2 g is rich in fats (~40%) and proteins (~38%) and plays a central role in the diet of the Kung San food gathering and hunting people of the Kalahari desert (Biesele et al. 1979, Fox and Norwood-Young 1982). The mongongo fruits abscise green when mature, and start ripening (skin color change to brown, flesh softening and taste development) a few days later.

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Seeds germinated after treatment with (2-chloroethyl)phosphonic acid (ethephon) (Keegan and Van Staden 1981). Seedlings were transplanted successfully in all orchards. At Neot Hakikar after a brief growth spurt in June the plants turned yellow, showed the typical leaf burn symptoms of NaCl damage, and subsequently died. At Qetura the main growth period occurred during the spring; in mid-summer growth slowed down. At the Besor location winter dormancy broke very late (in June), and growth continued until November (Fig. 4, 5). This location is much cooler than Qetura (Table 2). In all locations some of the trees showed signs of leaf yellowing, which was diagnosed as iron deficiency and corrected by applications of iron. The healthiest-looking trees are those growing at the Besor plot (Fig. 5).

Figure 2. Surviving yehib plant at Qetura (3 years old) (October 1988).

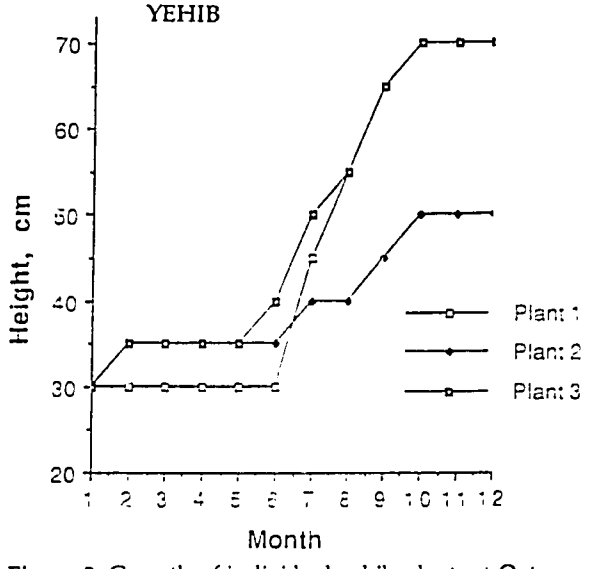

Figure 3. Growth of individual yehib plants at Qetura during 1987. Seedlings were planted in 1985. Plants died at all other locations.

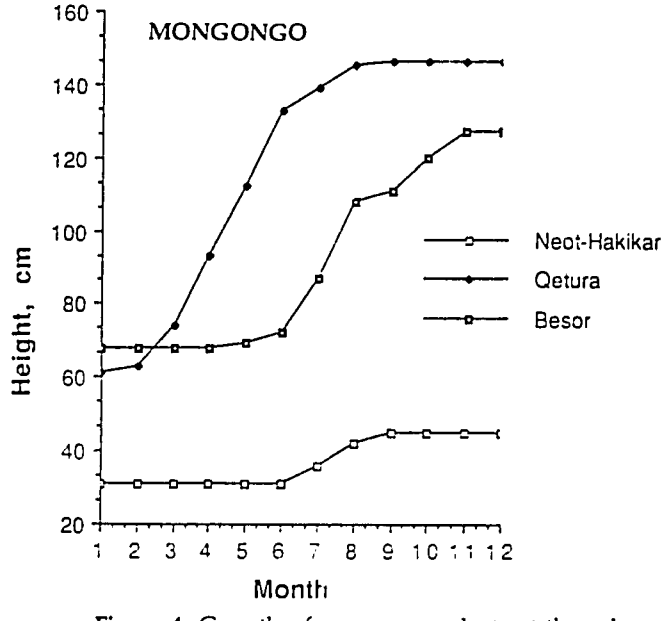

Figure 4. Growth of mongongo plants at three locations during 1987. Seedlings were planted in 1986. After initial growth at Neot Hakikar, all plants showed leaf yellowing followed by leaf burns from NaCl salinity and died. No. of plants: 29 (Qetura), 13 (Neot-Hakikar), 27 (Besor).

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Figure 5. Well-developed 3-year-old mongongo tree at Besor (October 1988).

Sclerocarya birrea subsp. *caffra*

Marula is a large, dioecious, deciduous tree which grows wild in northern South Africa and parts of eastern Botswana. The flesh of its fruit is very juicy and aromatic and is eaten fresh or processed, yielding quality jams, juices and alcoholic beverages. Inside the stone is a very small tasty nut. The fruit serves as an important source of vitamin C for the rural people (Shone 1979, Taylor 1986). When mature, the green fruit abscise followed by a skin color change to yellow, flesh softening and aroma development. These changes occur 7–10 days after abscission. Recently Prof. Holtzhausen (pers. communication) of the University of Pretoria selected improved clones producing large fruits up to 100 g in weight and with a variety of skin colors.

Seeds germinated after the operculum had been opened (Teichman et al. 1985). All plants were transferred successfully to the orchards. Breaking of winter dormancy occurred at Qetura first, then at Besor and Neot Hakikar. The slowest growth rate was recorded at Neot Hakikar. While growth was steady at Besor, at Qetura, rapid growth occurred from June to August followed by slower growth in September and October (Fig. 6,7). Neot Hakikar is characterized by high salinity due mainly to NaCl, and many plant species failed to survive there. Marula did not show any signs of salinity leaf burns. At Qetura three-year-old male and female trees started to flower and fruit developed.

Stenocereus gummosus

Pitahaya agria, a columnar cactus which grows wild in the Sonora and Baja California deserts of Mexico, produces variously colored edible fruits resembling those of prickly pear. In many cases the thorns of the fruits abscise upon ripening. The seeds are small and can be eaten without difficulty, unlike those of the prickly pear (Felger and Moser 1976).

The seeds germinated rapidly; however, first development was very slow, and it took two years for seedlings to reach a size suitable for transplanting (a height of ca. 10–15 cm). The slowest growth rate was at Neot Hakikar. Cessation of growth occurred only during the mid-winter monnths (December, January, and February). At Qetura three-year-old plants reached a total shoot length of 160 cm (Fig. 8, 9).

Casimiroa edulis

White sapota is a medium-sized evergreen tree from central America which can be found in backyard gardens. Growers of rare fruits in California and Florida have selected a number of high-yielding cultivars with improved fruits. The fruits are medium to large with a thin green-yellow skin and cream-white sweet flesh (Batten, 1984). Our seeds were obtained from the collection of Mr. and Mrs. Chambers of Fallbrook, California and from trees growing in Israel.

The seeds germinated easily and seedlings transplanted well at all locations. At Neot Hakikar the plants turned yellow with severe symptoms of NaCl leaf burn; they survived for a while and then died. Fig. 10 shows plant growth at Besor and Qetura. At Qetura growth started in March/April and slowed down in the hottest

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months, namely July and August. At this time the leaves showed some symptoms of yellowing and tip burns, which vanished in the autumn. Despite these difficulties, development at Qetura is satisfactory (Fig. 11). At Besor the fastest growth occurred in May–August, and damage to leaves was not observed.

Ziziphus mauritiana

Ber is a medium-sized evergreen thorny tree believed to be of African origin. Ber is grown commercially on a wide scale in the hotter areas of India, and is reported to be salt- and drought-tolerant (Alexander 1984). The fruits can reach the size of a plum and when ripe develop a thin, yellow-brown skin enclosing a tasty, white, sweet flesh.

Many cultivars are known in India of which two, 'Gola' and 'Seb', were introduced by us to Israel. They were grafted onto *Z. spina-cristi* (native to our region) and onto *Z. abyssinica*. Development at the various sites on each of the two rootstocks is successful; a one-year-old plant at Qetura is shown in Fig. 12.

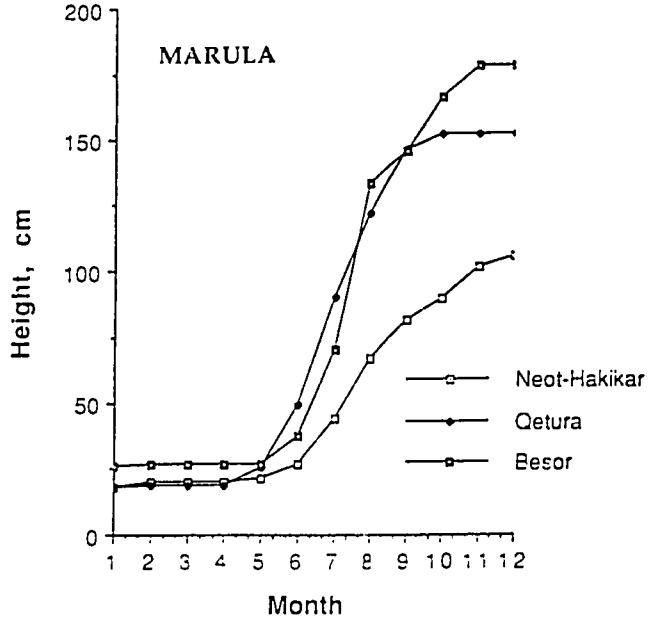

Figure 6. Growth of marula plants at three locations during 1987. Seedlings were planted in 1986. No. of plants: 30 (Qetura), 29 (Neot Hakikar) and 30 (Besor).

Figure 7. Fast-development 3-year-old marula tree at Qetura (October 1988).

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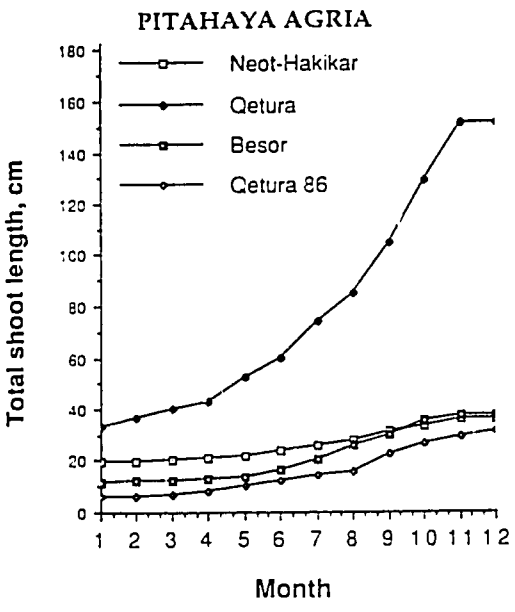

Figure 8. Growth of pitahaya agria plants at three locations during 1987. Seedlings at Neot-Hakikar and Besor were planted in 1986. Since seedlings at Qetura were planted one year earlier, growth in 1986 is included. No. of plants: 30 (Qetura), 20 (Neot-Hakikar), 30 (Besor).

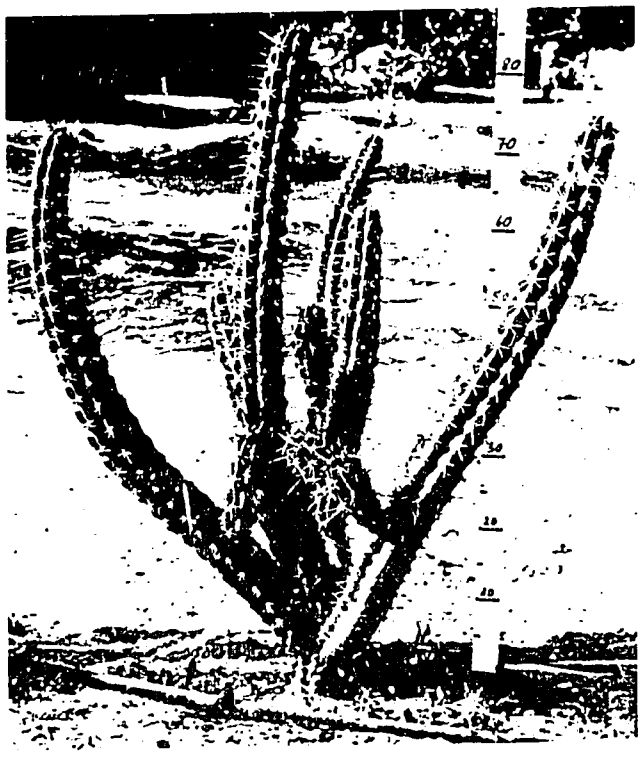

Figure 9. Pitahaya agria cactus (3 years old) at Qetura (October 1988).

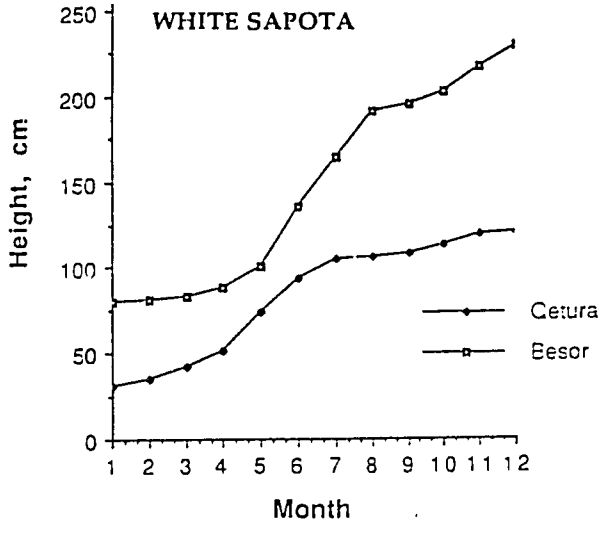

Figure 10. Growth of white sapota plants at two locations during 1987. Seedlings were planted in 1986. No. of plants: 14 (Qetura), 30 (Besor). All the white sapota plants died at Neot Hakikar after showing symptoms of severe leaf burn from NaCl salinity. At Qetura some plants showed leaf yellowing, especially during mid-summer months.

Figure 11. White sapota (3 years old) at Qetura (October 1988).

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Figure 12. One-year-old ber tree, 'Gola' cultivar, grafted on *Ziziphus spina-cristi* at Qetura (October 1988).

PROBLEMS

The first problem one faces when seeds are collected from the wild is that they often fail to germinate or that the germination rate is low. In the wild it is sufficient for some seeds to germinate every few years to ensure a steady population. Indeed, one of the mechanisms by which a population maintains itself under drought conditions is by staggering germination over a long period of time (Koller 1972). This is the case for the mongongo and marula which we collected from Botswana. Some work has already been done by various authors for both species. Mongongo can germinate efficiently if the exocarp is removed and the seed treated with either ethylene or ethephon (Keegan and Van Staden 1981). Marula can be forced to germinate by opening the operculum found in the very hard and thick exocarp (Teichman et al. 1985). Using these techniques we obtained over 80% germination for mongongo and 100% for marula. All other species germinated without special difficulty.

The next stage after establishment in the nursery is planting the seedlings at the various locations. Among the species studied, yehib showed a very high mortality rate. While the reason has not yet been established, we speculate that damage to the very long roots in the shallow nursery containers may have been partially responsible. We found that growth rate of the roots was 15 times faster that of the shoots. It appears that Besor is too cold for yehib, since during two consecutive years it died in the spring after a spell of low temperatures. In any case, this shrub grows very slowly. Despite these difficulties, several yehib plants at Qetura are now three years old and are continuing to grow. Vegetative propagation will be considered in the future. In addition, as soon as seeds become available from these plants we will try to sow seeds directly in the field in order to avoid damage to the root system.

There is no way of predicting the success of the various species at each locations. Both marula and mongongo were introduced from Botswana (a semiarid zone), yet there are considerable differences in performance between the two species. Mongongo failed at Neot Hakikar, probably due to NaCl salinity. Marula is growing well in all locations despite some inhibition of growth at Neot Hakikar. In the latter orchard only a few species have survived and are still growing. These include ber (which was introduced from India) and various cacti including pitahaya agria but excluding *Hylocereus* species, which suffered both from the extreme light and from the extreme salinity. Ciruelo is also growing very well at this location. The sulfate salinity at Qetura is less harmful to the new plant introductions than the NaCl salinity characteristic of Neot Hakikar. Mango and pum-

melo on a proper rootstock (13-I and sour orange, respectively) are grown commercially at Qetura, but are unable to survive at Neot Hakikar. White sapota grows well at Besor. It seems to tolerate cold weather but not very high temperatures. Given special care and proper selection of rootstocks and cultivars, the plant might also be grown at Qetura. To draw definite conclusions about the performance of a species at a particular location it is obligatory to test *in situ*. Aside from simple survival, successful economic performance, which depends on yields and product quality, requires evaluation.

Selection of rootstocks and scion cultivars will have to be performed for promising species in the future. Correspondingly, proper vegetative techniques will have to be developed for each of the plant species that grows successfully. These rare and wild fruit trees deserve much more attention from the scientific community than they have so far received.

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