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Beginnings of Fruit Growing in the Old World

Olive, grape, date, and fig emerge as important Bronze Age additions to grain agriculture in the Near East.

Daniel Zohary and Pinhas Spiegel-Roy

Fruit trees constitute an important element of food production in the countries bordering the Mediterranean Sea. The long standing of their economic importance is amply reflected in classical traditions. Five of the Biblical seven species (*1*) are fruit trees. Olive oil, wine, dry raisins, dates, and figs were, and still are, major agricultural products of the Near East and the Mediterranean Basin. Compared to the information available on the origin of cultivated cereals and pulses in the Old World, evidence on the beginnings of fruit growing is fragmentary. Yet recent examinations of plant remains in Neolithic and Bronze Age sites in the Near East and Greece have led to several critical discoveries which indicate that olives, dates, and probably also grapes, figs, and pomegranates were already under cultivation in protohistoric times. In this article we review the evidence we already have for answering the questions: (i) Which fruit trees were cultivated early in the Near East and what were their wild progenitors? and (ii) When and where were these plants brought under cultivation? As in previous evaluations of the origin of the Old World cereals (*2*) and pulses (*3*), the analysis is based primarily on two kinds of information: (i) "fossil" evidence obtained from examinations of plant remains in archeological excavations, and (ii) clues provided by living plants and particularly by wild relatives of the crops concerned. In addition, we evaluate several aspects of the genetic systems operating in the fruit trees and relate them to domestication. Attention is focused on the significance of the shift to vegetative propagation, and the possible role of hybridization between wild and cultivated forms in the establishment and expansion of cultivars.

Olive (Olea europaea L.)

Olives make their appearance in Palestine in the fourth millennium B.C. Numerous well-preserved carbonized olive stones (Fig. 1) were discovered in the Chalcolithic Teleilat Ghassul (3700 to 3500 B.C.) north of the Dead Sea (*4*), in close association with cereal grains, dates, and pulses. These finds, from a classic Chalcolithic site, are supplemented by admirably preserved stones excavated in the "Cave of the Treasure" near Ein Geddi (3200 to 3100 B.C.) (*5*) and stones and wood charcoal retrieved from Chalcolithic horizons (3200 B.C.) of Tell Mashosh, 15 kilometers east of Beersheva (*6*). Some centuries later olive remains abound in early Bronze Age (2900 to 2700 B.C.) Arad (*7*) and early and middle Bronze Age Lachish (*8*). Carbonized stones and charred olive wood are available also from early and middle Bronze Age Ta'anach (Tell Taannek) and Afeq (*9*). So far there have been few early finds of olives outside Palestine. Helbaek (*10*) reported olive remains from third millennium Tell Soukas, Syria, and Renfrew (*11*) recorded them from early Minoan Myrtos in Crete. In the middle and late Bronze Age, olive cultivation (and the olive oil industry) seems to have been well established throughout the areas bordering the Mediterranean Sea, from Palestine and Syria to Greece. Carbonized stones

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occur in quantities in Lachish (*8*) and other locations in Israel (*12*), in Apliki, Cyprus (*13*), and in Crete and mainland Greece (*14, 15*). Olive branches and olive fruits are important objects in Minoan art (*14–16*) and are occasionally found in decoration of other Bronze Age pottery and in Bronze Age graves. The olive does not appear to have played a major role in the agriculture of Egypt or Lower Mesopotamia. But the importation of olive oil from Palestine to Egypt is documented in Old Kingdom Egypt (*17*).

The question arises whether the carbonized stones retrieved from Chalcolithic and early Bronze Age sites represent cultivated olives or fruits collected from the wild. Wild olives still grow today in Palestine, and the stones of wild and domesticated oil-olive forms overlap considerably in size. However, for one of the key sites, Teleilat Ghassul in the Jordan Valley, a reasonable deduction can be made. No wild olives occur today in the Jordan Valley and the adjacent escarpments, as the region is too dry for the plant to succeed. The nearest areas that support wild olives in Israel and Jordan are the western flanks of the Judean Hills and Mount Carmel. This seems to indicate that the olives at Teleilat Ghassul were products of cultivation. They were probably raised under irrigation, as olives are today in Jericho or in Beisan.

The two main traits that characterize olives under domestication and set them apart from their wild relatives are a larger fruit size and a higher oil content. This development involves primarily the fleshy, oil-containing mesocarp. The increase in the size of the stone is less pronounced. In addition, domestication has changed the reproductive biology of the tree. Wild olives reproduce from seeds. Cultivated varieties are maintained by vegetative propagation and are, in fact, clones. Vegetative propagation depends primarily on utilization of knobs (ovuli) that develop at the base of the trunk and root easily when cut off. Alternatively, trees might also have been vegetatively propagated by truncheons or even by cuttings.

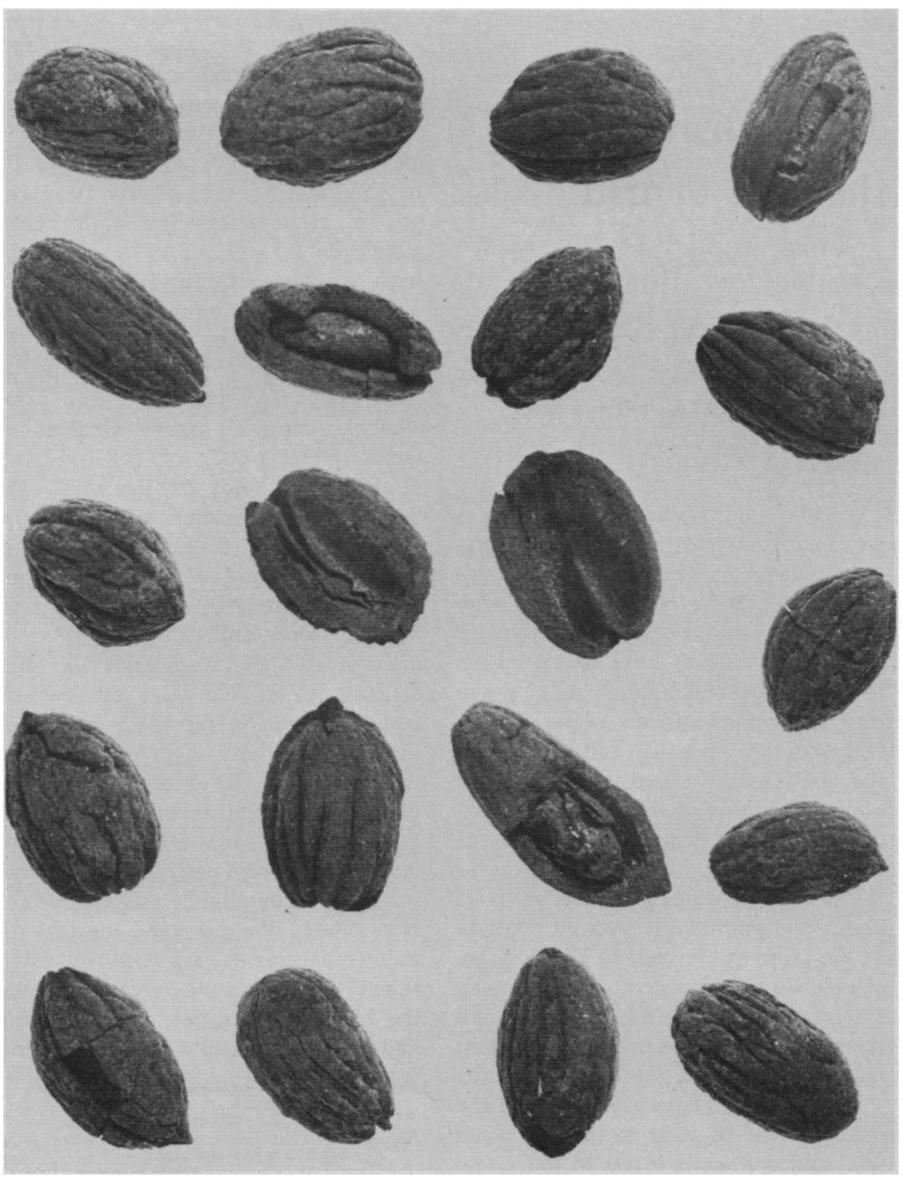

Fig. 1. Carbonized olive stones from Chalcolithic Teleilat Ghassul (× 2.3).

As with numerous other fruit trees, the shift to vegetative propagation is the cultivator's countermeasure to the genetic system operating in *Olea*. Wild, sexually reproducing olive populations maintain a considerable amount of genetic variation. Cultivated clones are usually extremely heterozygous and segregate freely when progeny are tested. In fact, most seedlings raised from a cultivar resemble wild forms in their morphology and are useless in terms of fruit quality. Consequently propagation from seed is impractical in olives under cultivation. In order to fix desired genotypes, the grower has to resort to clonal propagation. Seedlings can be used only as a variable raw material for selection of new clones. Today such screening is being performed in the few olive breeding programs that have been initiated. But spontaneous or subspontaneous seedlings have undoubtedly accompanied olive agriculture from its start, and rare individuals showing superior performance may have caught the eye of early cultivators and been picked up as new clones.

A single wild olive is closely related to the domesticated fruit tree and is distributed in more or less the same geographic and climatic belt as olive agriculture. The cultivated olive is interfertile with and morphologically closely related to a group of wild and "weedy" forms conventionally classed as *O. oleaster* Hoffmanns and Link, or more appropriately as *O. europaea* L. var. *oleaster* (Hoffmanns and Link) Fiori. These wild olives are widely distributed over the entire Mediterranean Basin. They are distinguished from the cultivars primarily by their small fruit size and lower oil content. When not coppiced and reduced to shrub (or even dwarf shrub) dimensions by the ax and the goat, *oleaster* individuals attain the size of small trees. In some areas of olive cultivation, *oleaster* plants are also extensively used as stock material onto which cultivated varieties are grafted.

Some botanists, and particularly Turrill (*18*), consider the widely variable *oleaster* olives as secondary derivatives,

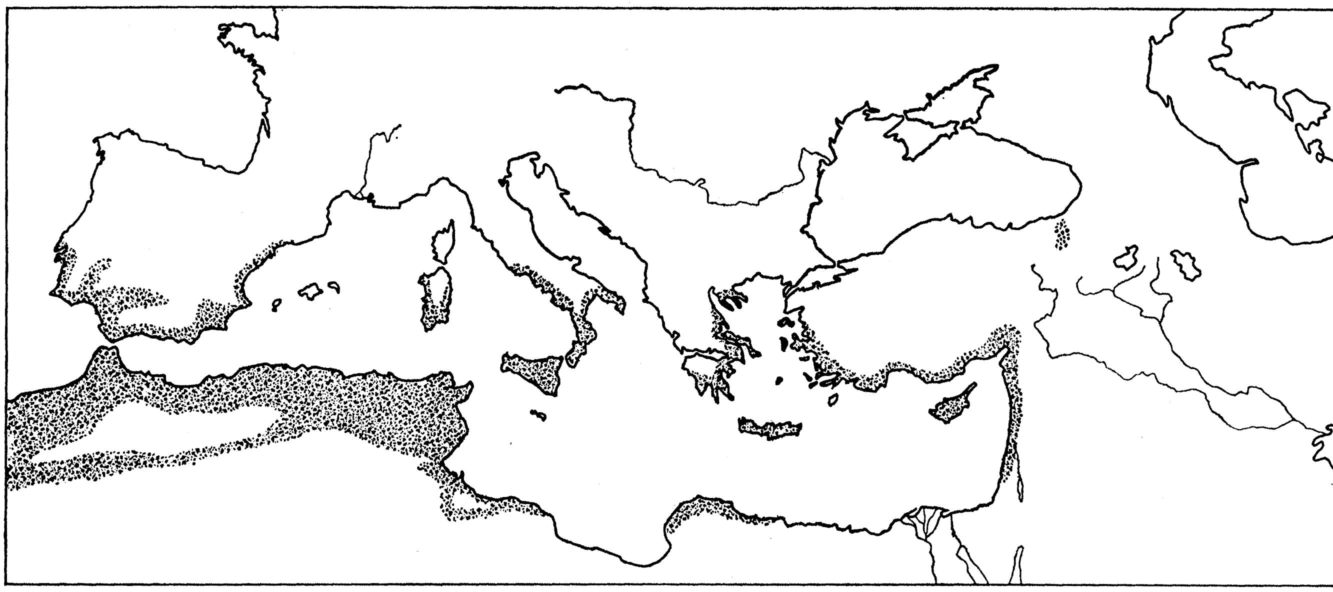

Fig. 2. Distribution of wild olive, *Olea europaea oleaster.*

that is, as escapees from cultivation. However, a close examination of their ecology and distribution indicates that this assumption is incorrect. In numerous areas along the shores of the Mediterranean Sea (Fig. 2) *oleaster* olives occupy niches not disturbed by cultivation and thrive as an important constituent of garigue and maquis evergreen plant associations. Under such conditions *oleaster* forms are particularly common in the lower-altitude belt (0 to 300 m) along the Aegean shores, the coast of southern Turkey, and the maritime belt of Lebanon and Israel, to as far south as Mount Carmel. A similar participation in Mediterranean sclerophyll communities is reported from the Çoroch Valley in northeastern Anatolia (*19*) and from Cyrenaica, Tunisia, Algeria, Morocco, southern Spain, southern Italy, and several other West Mediterranean countries (*20*). In all these niches *oleaster* olives are apparently genuinely wild, like the oaks, pistachios, and other trees and shrubs with which they grow. What makes the wild *oleaster* picture complex is that wild-looking olives also frequently grow in secondary habitats, such as at the edges of fields or in abandoned terrace cultivation. Here they are obviously feral, and since *oleaster* olives are extensively used as stock material in olive plantations they also commonly survive as escapees.

Thus in the Mediterranean Basin olives constitute a complex of wild forms, weedy types, and cultivated varieties. Wild *oleaster* forms occupy primary niches. Secondary feral forms, escapees derived from grafting stocks and segregating spontaneous seedlings, occur in disturbed areas and abandoned cultivation. Superimposed on this wild and feral background is olive agriculture with its numerous cultivated clones. Significantly, cultivated *europaea* varieties show climatic and edaphic preferences very similar to those of the wild forms. Both are typical Mediterranean plants. Also significant are the blurring of morphological boundaries between *oleaster* forms and *europaea* cultivars, and the presence of parallel variation in wild forms and in trees under cultivation. These morphological patterns indicate strongly that wild *oleaster* and cultivated *europaea* are genetically loosely interconnected and comprise a single wild and cultivated species complex. This idea agrees very well with the archeological evidence. The earliest archeological records of olives come from lands bordering the east shores of the Mediterranean Sea—a territory where genuinely wild *oleaster* olives still thrive today. Hence, on the basis of the combined evidence, we conclude that the East Mediterranean wild *oleaster* olives should be considered as the stock from which the cultivated olive was derived, and the Levant as the place where the olive was probably first brought into cultivation.

Grape (Vitis vinifera L.)

The grape is the second important horticultural element that characterizes the lands bordering the Mediterranean Sea. Compared to the olive, *Vitis* thrives in cooler and more humid climates. Viticulture extends farther north and succeeds on the northern fringe of the Mediterranean region.

Fruits of wild *Vitis* were apparently utilized long before the domestication of this plant. Carbonized pips of grapes have been discovered in numerous prehistoric sites in Europe, particularly northern Greece, Yugoslavia, Italy, Switzerland, Germany, and France (*21, 22*). In this early material, the morphology of the pips conforms with that of local wild *silvestris* grapes. These pips probably antedate viticulture and represent material collected from the wild.

Early signs of grape cultivation come from early Bronze Age Palestine, Syria, Egypt, and the Aegean area. Pips and parched berries (containing two or three pips) were discovered in early Bronze Age Jerico (*23*). These finds have been complemented by similar remains in contemporary (2900 to 2700 B.C.) Arad (*7*). The latter site has also yielded two samples of charred wood of *Vitis*. The Arad berries are still small, and the pips are roundish and relatively short-beaked. But since wild *Vitis* is absent in Israel, the combination of pips and wood charcoal provides solid proof that grapes were cultivated in the area in the early third millennium. Additional finds in Israel come from early Bronze Age Tell-ed-Duweir (*22*) and Lachish (*8*), as well as middle Bronze Age Ta'anach (*9*). Even earlier finds (a single imprint in a potsherd in Hama and a few dried pips in a tomb at Omari) are reported from Syria and Egypt (*13*).

In the Aegean area pips approaching cultivated *vinifera* in their width-length

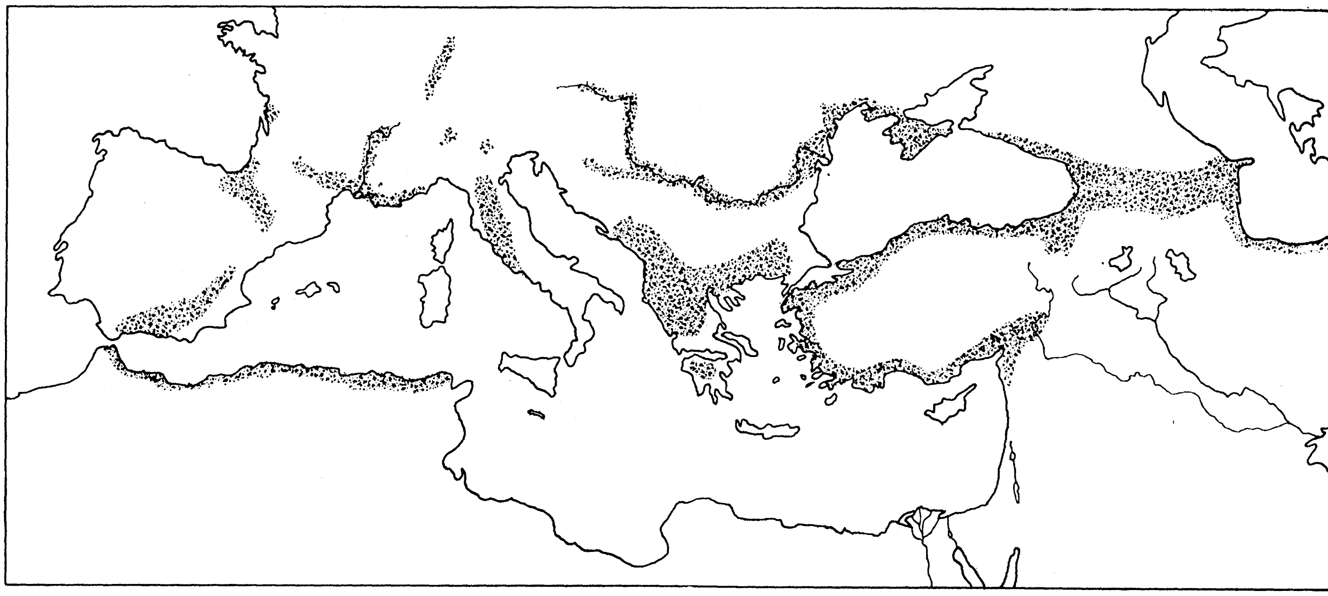

Fig. 3. Distribution of wild grape, *Vitis vinifera silvestris*.

index occur in the early Bronze Age Dikili-Tash (*24*), and in the early and middle Helladic levels of Lerna, in Argolis (*25*). Remains of grapes are also reported from early Minoan Mytros in Crete (*11*); Troy and Beycesultan in west Turkey (*25*); and Apliki (*13*) and Kalopsidha (*26*) in Cyprus. Finally at Sitagori, northern Greece, Renfrew (*11*) recovered a series of pips dating from between 4500 and 2000 B.C. and observed a definite shift from *silvestris*-like material in the lower levels to *vinifera*-like pips in the upper level, suggesting the emergence of viticulture in Macedonia well before 2000 B.C. The successful establishment and the large-scale utilization of *Vitis* in the second millennium B.C., both in the Levant and in the Aegean belts, is also indicated by Bronze Age art, remnants of vessels for wine storage, and references to raisins and wine in early tablets. Viticulture was apparently introduced to the western Mediterranean Basin by the Etruscan, Greek, and Phoenician colonists (*27*).

The impact of domestication on the grape is apparent in several plant traits. Cultivated varieties produce larger and sweeter berries than the wild forms. The increase in fruit size is accompanied by a change in the size and shape of the pips. As with the olive, there is a characteristic shift from the wild mode of sexual reproduction to vegetative propagation, and grape clones are highly heterozygous and segregate freely when progeny are tested.

A conspicuous feature of domestication is the change in sex determination. Wild forms of the grape are dioecious. Fruit setting in the wild depends on transfer of pollen from male plants to female receptors. In nearly all cultivated varieties the flowers contain both pistils and anthers, and the hermaphroditic condition ensures fruit setting without the need for pollen donors (*28*). Sex determination in *Vitis* is apparently governed by a series of three alleles (*29*). Female individuals are homogametic; that is, they carry a homozygotic recessive genotype (designated FF by French workers and Su^M Su^M by American workers) that suppresses the development of anthers. Males are heterogametic, that is, heterozygous for a dominant maleness-conferring allele (genotypic constitution MF or Su^F Su^M). The hermaphroditic condition is apparently governed by a third allele (H) which is dominant over F and recessive to M. Most cultivated clones are still heterozygous and show an HF constitution.

The relationships between wild *Vitis* species and the cultivated grape have been examined by several workers (*30*). The cultivated grape (*V. vinifera* sensu stricto) is fully interfertile with an aggregate of wild and feral forms which are conventionally classed under *V. silvestris* C. C. Gmelin, or more appropriately *V. vinifera* L. subsp. *silvestris* (C. C. Gmelin) Hegi. These wild grapes are dioecious, bear relatively small and acid berries, and can also be recognized by their smaller and broader pips. *Silvestris* forms are widely distributed over southern Europe and western Asia from the Atlantic coast to the western Himalayas. They are primarily forest climbers and seem to be at home in the humid and climatically mild Hyrcanian forest belt south of the Caspian Sea and the Pontic belt along the south coast of the Black Sea. *Silvestris* vines abound also in the cooler mesic northern fringes of the Mediterranean sclerophyll vegetation belt from Turkey and the Crimea through Greece and Yugoslavia to Italy, France, Spain, and northwest Africa (Fig. 3). Moreover, along the Rhine and the Danube, wild grapes penetrate deep into Europe.

The boundary between cultivated clones and wild forms of *Vitis* is blurred by the presence of weedy forms, escapees and secondary hybridization derivatives. Spontaneous hybridization between wild plants and cultivars has been noted repeatedly where *silvestris* vines grow in close proximity to vineyards. Thus also in *Vitis* we are faced with a variable complex of interfertile and loosely interconnected wild forms (growing in primary habitats), escapees and seed-propagated weedy types (which occur mainly in disturbed sites), and the cultivated clones. The geographic distribution of the *silvestris* vines is extensive, and the preagricultural distribution patterns of the wild vine have probably been blurred considerably by weedy forms. Yet there can be little doubt that *silvestris* vines are in their wild home in the south Caspian belt, Turkey, and the Balkans. Furthermore, genuinely wild *silvestris* forms occur as far south as the Taurus and Amanus ranges. On the whole, the situation in *Vitis* parallels that in *Olea*. The earliest archeological indications available on viticulture come from the Levant and Greece. In this general territory we still find wild forms that could have served for derivation of the cultivated grape. But while wild *oleaster* olives are confined to the typical Mediterranean climate, *silvestris* vines thrive in cooler and more mesic conditions. These adaptations are paralleled under cultivation. Thus, we conclude that the area in which *Vitis vinifera* domestication was most likely initiated is again the Near East and the Aegean belt.

Date (Phoenix dactylifera L.)

The earliest remains of what seem to be cultivated dates have been found in the protohistoric Near East. Numerous stones were recovered by Seton Lloyd in the Ubaidian horizon (about 4000 B.C.) at Eridu, Lower Mesopotamia (*31*). In Palestine carbonized stones (Fig. 4) were discovered in the classic Chalcolithic (3700 to 3500 B.C.) site of Teleilat Ghassul (*4*). Dried date kernels have also been retrieved from the Chalcolithic bed (3200 to 3000 B.C.) of the Cave of the Treasure in Nahal Mishmar (*5*). Finally, a single date stone is available from early Bronze Age Jericho and few more from middle Bronze Age beds in this site (*23*).

From the Bronze Age on, date cultivation seems to have become well established in the warmer sections of the Near East. Dates are frequently mentioned in Sumerian and Assyrian documents (*32*), are also represented in Mesopotamian wall painting and sculpturing, and abound in Egyptian tombs from the Middle Kingdom on (*33*).

Also in the date palm, domestication has led to a considerable change in the size and quality of the fruit. Wild dates produce small and usually nonpalatable fruits. In cultivated plants, fruits are larger and contain a considerable amount of sweet pulp. Under cultivation vegetative propagation is universal. Suckers start to appear several years after the setting of the mother plant and they can be separated and replanted. Dates are dioecious, and female clones are artificially pollinated. This is a very old practice (*32*) which enables the cultivator to keep only a few male individuals. Cultivated clones are usually extremely heterozygous. Seedlings segregate freely and manifest a more or less 1 : 1 sex ratio (*34*).

The wild stock from which the cultivated date may have derived is recognized at least in general terms. The cultivated date is closely related to and interfertile with a variable cluster of wild and feral dates growing in the southern parts of the Near East. Botanists place these noncultivated dates, with characteristic small fruits, within *Phoenix dactylifera* and note that they spontaneously hybridize with the cultivated clones. Several other wild *Phoenix* species which show close genetic affinities with the cultivated dates are distributed over North Africa, Arabia, and southern Asia. Prominent among them are the East African forms grouped in *P. reclinata* Jacq. and the northwest African palms classified as *P. atlantica* Chev. These wild dates also seem to hybridize spontaneously with the local cultivated clones (*35*). A local and isolated type occurring in Crete has been described as *P. theophrasti* (*36*). More distant but still interfertile with the cultivated date are the Indian and Pakistani *P. sylvestris* Roxb. and the Atlantic *P. canariensis* Hort.

Thus, in the date palm we are also faced with a variable complex of wild forms, weeds, segregating escapees, and cultivated clones which are all genetically interconnected by occasional hybridization. It is often difficult to decide whether noncultivated material is genuinely wild or whether it represents weedy forms or secondary segregating seedlings derived from cultivated clones. Some of the more distant wild types, such as the Indian *P. sylvestris*, have solitary trunks, do not produce suckers, and are adjusted to rainy conditions (*37*). These traits seem hardly compatible with the ancestry of the cultivated date in which pollination and fruit set succeed only in a dry desert climate. But in some areas in the Near East noncultivated *dactylifera*-like dates grow under typical desert conditions and resemble the cultivars also in their ability to branch and produce suckers. What is more important, they seem to occupy genuinely wild niches. Prominent among these locations are lowland Khuzistan and the southern base of the Zagros Range facing the Persian Gulf. In these warm, dry territories, wild *dactylifera* palms with small and mostly unpalatable fruits thrive in gorges, wet rocky escarpments, seepage areas in wadi beds, and near brackish springs. Pabot (*38*) rightly stressed the fact that these dates constitute a dominant vegetation element in the area. Date palms that seem to be genuinely wild are also found on the southeast side of the Dead Sea (*19*). In addition, the presence of wild dates in the Near East in prehistoric times is indicated by pollen grains retrieved from middle and upper Paleolithic beds in Shanidar cave in Iraq (*39*).

The available archeological data as well as the information on the living palms seem again to focus on the Near East. The same area that furnishes the earliest indications of date palm cultivation also harbors wild forms from which the early cultivated clones could have been derived. Very probably the date palm was first brought into cultivation somewhere in the Lower Mesopotamian Basin.

Fig. 4. Carbonized date stones from Chalcolithic Teleilat Ghassul (× 3.3).

Fig (Ficus carica L.)

Early archeological records of figs are still sparse (*40*), but carbonized pips have been uncovered in Neolithic, Chalcolithic, and Bronze Age Jericho (*23*) and late Neolithic Gezer, Palestine (*41*). Fig remains including carbonized whole fruits are also available from late Neolithic Rachmani, Sesklo, and Dhimini in Thessaly and Olynthos in Macedonia (*11*, pp. 134–135; *15*). Pips and several whole fruits have been recovered from the early Helladic horizons of Lerna, Argolis (*25*). In the Bronze Age, figs seem to have been universal companions of olives and grapes in the lands bordering the East Mediterranean Sea. Documentation of fig cultivation in the land of Canaan in the third and second millennia B.C. is available from Egypt (*41*) and a beautifully preserved drawing of a fig harvest has been found in Khnemhoteps' grave (about 1900 B.C.) in Beni Hasan (*42*). Similar indications of fig cultivation from the third and second millennia B.C. are available from Syria and Upper Mesopotamia (*32*). During classical times, figs accompanied olives and grapes as the main horticultural elements of the rain-dependent agriculture in the Mediterranean Basin, providing fresh fruit in summer and sweet dry figs throughout the year.

Also in the fig, domestication brought about a considerable increase in the size of the fruit (syconium) and its sugar content, as well as a characteristic shift to vegetative propagation. Wild figs depend entirely on propagation from seed. Birds and fruit bats eat the ripe syconia and effectively disseminate the minute pips. Under cultivation, propagation is by cuttings. Fig cultivars are extremely heterozygous and, when progeny are tested, manifest wide segregation. Most of the segregating seedlings are economically useless (*43*).

Like other members of the genus, *Ficus carica* is very specialized in its pollination. This is carried out by a small symbiontic wasp, *Blastophaga psenes* L. The fig is dioecious and its male morph, the caprifig, produces syconia containing male flowers and short-styled gallflowers in which the *Blastophaga* larvae develop. The female morph, the true fig, develops syconia containing long-styled, female flowers. Wasps emerging from caprifig inflorescences are dusted with pollen and, when they enter the young true fig syconia, bring about fertilization. In some cultivated clones wild-type pollination is retained. Fruit development in the group of cultivars known as Smyrna figs depends on pollination by the *Blastophaga* wasp (*44*). But in numerous other fig clones known as common figs, pollination is no longer mandatory for fruit set. Seedless fruits develop parthenocarpically.

A whole cluster of nontropical wild figs is widely distributed over the Mediterranean Basin, southwest Asia, and northeast Africa and is closely related to the cultivated fig. Taxonomists have recognized several species (or "microspecies") in this group and have assembled all of them in a single natural entity (series *carica*). Some of these wild figs are not fully separated from each other morphologically and are best regarded as major ecogeographical races (*45*).

Noncultivated, *carica*-like figs are widely distributed over the entire Mediterranean Basin. They are particularly common in the Aegean belt and the Levant, where they thrive in rock crevices, beside springs, and in wet gorges. Certain identification of genuine wild *carica* forms in the Mediterranean countries is, however, vastly complicated by the massive occurrence of feral elements. A considerable proportion of the wild-looking figs thrive in secondary habitats (at the edges of plantations or in ruins, collapsed cisterns, cave entrances, or the like) and seem to be frequently derived from seed produced by local cultivated clones fertilized by pollen transported from wild-growing caprifigs (*46*).

In addition to this Mediterranean complex of interconnected wild, feral, and cultivated *carica* figs, wild figs form an important arboreal element in the lower zone of the mesic deciduous forests in the Colchic district of northern Turkey and the Hyrcanian district in northern Iran and adjacent Transcaucasia. Some authors include these tall, wild, forest forms within *F. carica* L. Others, particularly Russian botanists, treat them as independent species (*F. colchica* Grossh., and *F. hyrcanica* Grossh.). Finally series *carica* contains a whole aggregate of more xeric, shrubby types: *F. geraniifolia* Miq. in the Zagros Mountains and southern Iran, *F. virgata* Roxb. in Afghanistan, *F. pseudosycomorus* Decne. in the Negev, Sinai, and Egypt, and *F. palmata* Forsk. in Yemen and Ethiopia.

When all the available archeological clues and the information from the living plants are put together, we are again led to conclude that the earliest fig cultivation may have been practiced in the eastern part of the Mediterranean Basin. As with the other three fruits, this territory also harbors the closest wild relatives. These can be regarded as representatives of the ancestral wild stock from which the early domesticants were derived.

Other Early Fruit Trees

Several additional fruit trees make their appearance in Bronze Age Near East. But compared to the "horticultural staples" discussed above, they apparently played only a minor role in ancient food production. Two plants seem to have been prominent among these fruit trees.

1) Pomegranate (*Punica granatum* L.). Carbonized pips and fragments of pomegranate peels have been obtained from early Bronze Age Jericho (*23*) and Arad (*7*), and this fruit might have been utilized in Palestine even earlier. Remains of *Punica* have also been found in Nimrud (*47*), and pomegranates are clearly drawn on Egyptian tombs (*32, 42*).

The wild ancestor of the cultivated pomegranate has been satisfactorily identified. The cultivated varieties are closely related to wild and weedy forms that grow in masses in the south Caspian belt and in northeast Turkey (*19*). *Punica granatum* does not occur in the wild state in the Levant countries. Hence, the occurrence of *Punica* remains in early Bronze Age Palestine strongly suggests cultivation. In *Punica* also, domestication meant primarily an increase in fruit size and a shift to clonal propagation. Desired genotypes are easily maintained by cuttings.

2) Sycamore fig (*Ficus sycomorus* L.). Utilization of the sycamore seems to have been almost exclusively an Egyptian specialty and, apart from south Palestine, Cyprus, and a few other places, sycamore culture did not spread beyond the Nile Valley. But in Egypt *F. sycomorus* seems to have been an important cultivated plant in the Early and the Middle Kingdoms (*42*). Both the figs and the timber were extensively used. Wild *Ficus* forms closely related to the cultivated clones still thrive today in East Africa and the upper Nile Valley. Under cultivation the sycamore is easily propagated by means of cuttings, and fruit set no

longer depends on pollination by the tree's symbiotic wasp. Some cultivars are parthenocarpic; in others fruit ripening is initiated by surface gashing of the young syconia (*48*).

Discussion

The information available on the beginning of fruit growing from Near East sites is fragmentary and permits, at best, only preliminary conclusions. Yet if we take the available archeobotanical evidence at face value, we are led to the conclusion that fruit tree cultivation in the Near East came after the firm establishment of grain agriculture. Fruit remains seem to be rare or totally absent in the string of early Neolithic farming villages that evolved in the Near East and Greece in the seventh and sixth millennia B.C. They start to appear in early fourth millennium sites. At least olives and dates occur as integral elements of food production in Chalcolithic Palestine. In the Bronze Age the picture changes drastically: olives, grapes, and figs emerge as important additions to grain agriculture throughout the Near East, including the Aegean belt. Dates are cultivated on the southern fringes and in the warm river basins. All in all, the available archeological evidence points to the Near East as the territory where these classical fruit trees were first cultivated, and this is supported by what we know about the wild relatives. Wild olives, grapes, figs, and dates are widely distributed over the Mediterranean Basin and southwest Asia. Forms from which the cultivated clones could have been derived also thrive in wild niches in the Near East. Wild *Vitis* occurs in the northern sector. *Oleaster* olives grow along the coasts of the Aegean belt and the Levant. Wild forms of *Phoenix* border the Near East in the warm south, and wild figs that may be involved in the ancestry of the cultivated fruit abound all over the East Mediterranean belt. Thus, evidence from the living plants complements the archeological finds. Very probably olives, grapes, dates, and figs (as well as pomegranates) were first brought into cultivation in the same general area that, several millennia earlier, saw the successful establishment of grain agriculture in the Old World.

Genetically these fruit trees are characterized by the following features: (i) Their wild forms are cross-pollinated and wild populations manifest wild variation and maintain a high level of heterozygosity. Cultivated clones are, as a rule, extremely heterozygous and, when progeny are tested, segregate profusely to produce a multitude of variable, mostly unwanted types. (ii) All wild forms reproduce from seed; that is, in the wild state sexual reproduction prevails. Furthermore, this type of reproduction is coupled with a relatively long life span and extensive production of seed and seedlings—of which only a few succeed in replacing existing individuals and attaining maturity. Such a genetic system will favor few restrictions on recombination and considerable heterozygosity. Consequently, under domestication the maintenance of desired genotypes becomes practical only by vegetative propagation. Indeed, in these fruits domestication represents first of all a shift from sexual reproduction to vegetative propagation. The cultivated forms are clones maintained and multiplied by cuttings (in the grape, fig, pomegranate, and sycamore fig), by basal knobs (in the olive), or by transplanting offshoots (in the date). In all these classical fruits vegetative propagation is technically simple. The early cultivators did not have to resort to sophisticated techniques such as grafting. Wild olives, grapes, figs, dates, and pomegranates were thus "preadapted" for domestication, since they lent themselves easily to vegetative manipulation. This trait was probably decisive for their success in becoming the first domesticated fruit trees in the Near East (*49*).

The adoption of clonal cultivation means that the classic fruit trees, in the five or six millennia since their introduction into cultivation, have undergone very few sexual cycles. Cultivated clones persisted hundreds or even thousands of years. From the standpoint of evolution under domestication this means a severe restriction on selection. In other words, selection could have operated only during a limited number of generations, and we have to expect that the cultivars have not diverged considerably from their progenitor gene-pools. This is in sharp contrast to the grain plants, in which selection could have operated during thousands of generations. Indeed, the cultivated varieties of fruit trees can be regarded as exceptional, highly heterozygous individuals of their biological species, clones that excel primarily in fruit size and fruit quality. These clonal cultivars can be compared to exceptional human individuals and, when progeny are tested, follow Galton's law of filial regression toward the mean and produce numerous wild-looking derivatives. The absence of profound genetic changes in the classic fruit trees under domestication is also apparent in the trees' ecology. The climatic requirements of the cultivars closely resemble those of their wild relatives. Unlike cereals and pulses, the classic fruits have not been pushed much beyond the climatic requirements of their wild ancestors.

The shift from sexual reproduction to vegetative propagation also had an immediate effect on pollination and fruit set. Wild dates, grapes, and figs are dioecious, and in the wild state fruit formation depends on the availability of male individuals and on effective transfer of pollen to female recipients. Horticultural propagation of clones leads to a breakdown of the natural pollination system and places a serious limitation on fruit production. Under domestication fruit production is nevertheless safeguarded in several ways. (i) Orchards of date palms and Smyrna figs have remained dependent on pollination, but the wild-type pattern has been replaced by artificial pollination devices that require a limited number of male trees or a pollen supply from wild-growing individuals. (ii) Domestication has brought about a genetic shift from dioecism to hermaphroditism. Mutations leading to such alterations seem to have been unconsciously selected for in *Vitis*. (iii) Pollination in dioecious fruit trees has been dispensed with altogether and replaced by parthenocarpy. Genes inducing parthenocarpy have become incorporated into the common fig and into sultana and Corinth type grapes.

Parallel adjustment is also apparent in the hermaphroditic olive. Wild *oleaster* plants seem to be highly self-incompatible and fruit set in them depends on the availability of pollen grains from other individuals, that is, on numerous genotypes growing together in the wild. In contrast, numerous olive cultivars show a tendency toward a breakdown of the self-incompatibility mechanism and are partly self-fertile, and some set fruit even when grown as single clones.

Another basic fact that emerges from this review is that in each fruit tree the wild stock comprises a whole array of widely distributed ecogeographic races, or, in the cases of the palm and the fig, even a series of interfertile microspecies. Together with the wide variation in the wild background we also find for each fruit tree indications of spontaneous hybridization between wild and cultivated elements. In fact, wild forms and cultivated clones are not fully reproductively isolated from one another. They frequently grow side by side and are loosely interconnected by hybridization.

Such a diversified wild background, coupled with spontaneous hybridization between wild races and cultivated clones, was critical for the rapid buildup of variation under domestication. When the initial cultivated clones were moved into new locations (which were already on the fringe of their adaptation) they could have hybridized with locally adapted wild types. Such spontaneous crosses would have resulted in a whole swarm of segregating escapees, some of which may have been attractive to man. Incorporating genes adapted to local conditions, some segregants may have shown superior performance and the ability to thrive in new sets of climates and soils. Man was able to push such new cultivars into additional territories, and consequently contacts could be established with still other wild ecotypes leading to the initiation of new cycles of introgression. Expanding Bronze Age horticulture would thus have been provided with rich background resource of preadapted genes, and the situation in the Old World classical fruit trees seems to parallel the patterns already described in the cultivated grains (*50*). In conclusion, the formation of new cultivars in each fruit tree did not have to rely on the restricted gene pools present in the initial domesticants. Repeated gene "injections" from wild to cultivated forms probably enabled horticultural varieties to become established over most of the geographic ranges of the wild forms—in a matter of only a few millennia.

Summary

The article reviews the available information on the start of fruit tree cultivation in the Old World. On the basis of (i) evaluation of the available archeological remains and (ii) examination of the wild relatives of the cultivated crops, it was concluded that olive, grape, date, and fig were the first important horticultural additions to the Mediterranean grain agriculture. They were most likely domesticated in the Near East in protohistoric time (fourth and third millennia B.C.) and they emerge as important food elements in the early Bronze Age.

Domestication of all four fruit trees was based on a shift from sexual reproduction (in the wild) to vegetative propagation of clones (under domestication). Olive, grape, date, and fig can be vegetatively propagated by simple techniques (cuttings, basal knobs, suckers) and were thus preadapted for domestication early in the development of agriculture.

The shift to clonal propagation placed serious limitations on selection and on fruit set under cultivation. We have examined the consequences of this shift in terms of the genetic makeup of the cultivars and traced the various countermeasures that evolved to ensure fruit set.

Finally, it was pointed out that in each of these classic fruit trees we are confronted with a variable complex of genuinely wild types, secondary weedy derivatives and feral plants, and groups of the domesticated clones, which are all interfertile and interconnected by occasional hybridization. It was concluded that introgression from the diversified wild gene pool facilitated the rapid buildup of variation in the domesticated crops.

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46. Viable wild-looking feral seedlings of this derivation have been repeatedly encountered in northern Israel, western Turkey, and Greece. In the Aegean belt, where Smyrna-type figs are commonly grown, seed are disseminated in masses not only by man but also by birds and bats that thrive on the fresh supply they find in the fig orchards. Parthenocarpic figs too are occasionally pollinated by the *Blastophaga* wasps and produce viable seed. These give rise to a whole array of spontaneous, wild-looking seedlings. In Israel such feral descendants have been repeatedly detected by J. Galil (personal communication) in areas adjacent to common fig plantations near Safad, Upper Galilee.
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NEWS AND COMMENT

Strategic Arms Limitation (I): The Decades of Frustration

"*. . . [T]he advancement of science and technology can be like a whip, cracking over our heads, encouraging us to spend more and more money on national security. . . . But the goal of accumulating the very latest weapons in sufficient quantity to be completely safe, once and for all—that goal is an illusion, a dream.*"—*from* Khrushchev Remembers, The Last Testament.

For nearly 30 years, beginning not long after the detonation of the bomb at Hiroshima, the United States and the Soviet Union have been running a strategic arms race and engaging in strategic arms talks. The "asymmetry," to use a favorite word of arms control specialists, between the results of the race and the outcome of the talks is all too plain. The stocks of nuclear warheads and bombs possessed by the two nations are huge and still growing. The most recent result of the fitful process of arms negotiations has been to agree to put a ceiling or "cap" on the arms race at very high levels. The ceiling, decided at the Vladivostok summit last November (subject to further negotiations as to verification methods), would allow 2400 missiles and bombers to a side, with up to 1320 of the missiles permitted to be equipped with multiple, independently targeted warheads (MIRV's).

If such an agreement represents progress in strategic arms limitation, as many believe, it is a measure of the modesty to which U.S. and Soviet leaders have been reduced by the baffling complexities and dynamics of the arms race. The history of arms control is one in which the notion of success has continually been redefined in the face of onrushing technology. Usually, at each new turning point along the way "success" has come a step closer to being merely something less than total failure. For the problem of restraining strategic arms development has tended to become more difficult with every major new technological advance in weaponry—from A-bomb to H-bomb, from bomber to missile, from missile to antimissile, and from missile to MIRV.

This article, the first of two, is concerned with the period from 1945 through the 1960's to the beginnings of SALT. It reviews the turning points, the disappointments, the successes (such as they have been), and the changing concept of success. The second article will discuss SALT, the Vladivostok agreement, and the uncertain prospects for further gains in arms control.

The Soviets' rejection in 1946 of the Baruch Plan for international control of the atom prevented stopping the nuclear arms race before it could begin. Conceived largely by leading figures of the Manhattan project and presented by Bernard M. Baruch before a United Nations commission, this U.S. proposal today seems remarkable for its innocence and directness.

It called for the establishment of an International Atomic Development Authority that would assume exclusive control of "all atomic energy activities potentially dangerous to world security." Further, the proposed authority would make inspections worldwide and apply sanctions against any nation violating its rules. Once these arrangements came into existence, the United States would turn over to the new agency its stocks of atomic weapons and the technical information that went into producing them.

However altruistic and farseeing, the Baruch Plan could not overcome the deep suspicion and paranoia with which the Kremlin looked out upon the world. A number of years later, Nikita Khrushchev characterized the plan as an attempt by the United States to prevent development of atomic industry in other nations and to maintain its nuclear monopoly.

The monopoly ended in 1949, when the Soviet Union detonated an atomic device. With the Soviets now catching up with surprising speed, the United States soon became committed to the development of thermonuclear weapons of enormous yields, with the