ISSN 0312-8997

CONTENTS

Price $30.00

WANATCA YEARBOOK • Volume 26 • 2002

WANATCA Yearbook 2002

The Malay Apple,
Syzygium malaccense
(see article page 68)

West Australian Nut and Tree Crop Association (Inc)
Yearbook 26 • 2002
Registered by Australia Post: Publication PP632219/00017 ISSN 0312-8997

CONTENTS

West Australian Nut and Tree Crop Association (Inc)

WANATCA Yearbook

Volume 26

2002

References to the ATCROS Directory

Organizations which have their names underlined in the articles contained herein are listed in the ATCROS Directory at the website address <www.AOI.com.au/atcros>. Each organization's ATCROS reference (eg <A4321>) is given at the end of the relevant article.

This provides a route for checking current contact details of relevant tree crop organizations at any time.

West Australian Nut and Tree Crops Association (Inc.)

PO Box 565, Subiaco, WA 6008, Australia
wanatca@AOI.com.au
www.AOI.com.au/wanatca

Publications

The Association publishes a quarterly magazine *Quandong* and the *WANATCA Yearbook*. Members receive these publications as part of their current year subscription.

Membership

For current details of membership contact the Secretary, WANATCA, PO Box 565, Subiaco, WA 6008, Australia (e-mail: wanatca@AOI.com.au, website www.AOI.com.au/wanatca). Members are welcomed from within and beyond Western Australia, indeed about one third of the current membership is from outside Western Australia. Overseas members are encouraged, and pay only standard fees.

For further details of the Association see Inside Back Cover

WANATCA Yearbook: ISSN 0312-8997; Supplement to Quandong: ISSN 0312-8989

Typesetting and design: Tree Crops Centre, PO Box 27, Subiaco WA 6008.
Printed in Australia by Optima Press, Perth.

Submission of Articles

The WANATCA Yearbook is devoted to useful longer articles, likely to have continuing reference value, about any aspects of nuts, fruits, and other tree or perennial crops.

Articles would be gladly received from any source — there is no requirement to be a member of WANATCA. If the text is available on a computer or word-processor disc, this is greatly appreciated. Text and enquiries can also be sent by fax or e-mail.

The WANATCA Yearbook is produced at the Tree Crops Centre, Perth, for the West Australian Nut & Tree Crop Association Inc.

Please send articles or enquiries to:
The Editor, WANATCA Yearbook, PO Box 565, Subiaco, WA 6008, Australia
E-mail: wanatca@AOI.com.au • Fax: +61-8-9388 1852

West Australian Nut & Tree Crop Association (Inc)

Founded in 1974, the Association has built up a wide membership among professional growers, amateurs, researchers, horticultural bodies, libraries, nurseries, and investors. Members are based throughout the State, all over Australia, and in many overseas countries.

Membership fees cover subscriptions to all WANATCA publications. Currently these are our quarterly magazine, **Quandong**, and the **WANATCA Yearbook.**

Quandong has details of forthcoming Association meetings, events, and field trips, book reviews, news items of interest, reprints of short articles drawn from world-wide sources, members' comments and queries, and notes on sources of trees, seed, materials and services.

The **WANATCA Yearbook** is our major research publication, with original articles of permanent interest. It is indexed as part of the global coverage of the U.S.-based Biological Abstracts Service.

The **Australasian Tree Crops Sourcebook (ATCROS)** was our major reference work, containing regularly-updated tables of all sorts of useful material about tree crops (common and botanical names, growing conditions, recommended areas etc), membership lists, lists of useful tree crop organizations world-wide, and a commercial-sources list, acting as a Directory of Tree Crop Services for the whole of Australia, New Zealand, and adjacent areas. Relevant services (eg seed suppliers) were listed world-wide. This information has now been updated and converted into a major World Wide Web site on the Internet — address is **<www.AOI.com/atcros>**.

There are various classes of **membership.** The standard grade is **Full Membership.** It is open to individuals, families, and any form of organization (companies, research units, libraries, etc.). New Full Members will be accepted on application; no entrance fee is charged. **Student Membership** is a concessional rate for current-year students unable to pay full rate. **Life Membership** is available to existing individual members of at least 3 years standing who wish to commute all future payments into a single sum. **Corporate Membership** is open to organizations involved in tree-crop enterprises. **Overseas Members** are welcomed and pay no more, although they may optionally receive publications by air-mail for a small premium.

All subscriptions (except for Life Members) run for a year of four consecutive quarters (1=Jan-Mar; 2=Apr-Jun; 3=Jul-Sep; 4=Oct-Dec). New members may join at any time and will receive four issues of *Quandong magazine* and one issue of *WANATCA Yearbook* during the subscription year.

West Australian Nut & Tree Crop Association Inc
PO Box 565, Subiaco, WA 6008, Australia.
E-mail: wanatca@AOI.com.au • Home Page: www.AOI.com.au/wanatca
You can now subscribe on-line at our home page

BREEDING BETTER HAZELNUT VARIETIES

— THE GENETIC RELATIONSHIPS AMONG THE CORYLUS SPECIES

PATRICK CAVANAUGH §

Pacific Nut Producer

PO Box 626, Clovis, CA 93613, USA

<MalcolmMed@aol.com>

Over the past five years, landmark hazelnut variety work has been accomplished in the United States by Ph.D student Veli Erdogan. So thorough was the work it will undoubtedly be cited for the next century by future researchers studying the relationships between hazelnut species.

For the study, Erdogan, along with his major professor Shawn Mehlenbacher at Oregon State University (OSU) at Corvallis, utilised the collection of hazelnut plant material from the OSU Hazelnut Breeding Program and the USDA repository in Corvallis. Because Erdogan has completed the work and has returned to his native Turkey to teach and complete mandatory military service for his country, Mehlenbacher reported on the research at the recent 85th Annual Nut Growers Society meeting in Portland, Oregon.

While taxonomists recognise about 25 different hazelnut varieties, Erdogan and Mehlenbacher focused on the similarities of the 10 most common species recognised:

I The European hazelnut, *Corylus avellana*, which is native to Europe and Turkey. This is the species that we grow; 'Barcelona' is *Corylus avellana*.

2 The American Hazelnut, *C. americana* species, is native to the Eastern USA, where eastern filbert blight came from.

3 *C. heterophylla* is native to Eastern Asia.

4 C. cornuta is native to North America, mostly the eastern part.

5 C. californica is native to Oregon and adjacent areas of California, Washington and British Columbia.

6 C. sieboldiana is another East Asia species.

These first six species are shrub species with multiple stems. The next four species are Tree Hazels, fairly large trees.

7 The *C. colurna* species is the Turkish tree hazel, native to Turkey, the Balkans and Northern Iraq.

§ Member, WANATCA

8 The Chinese tree hazel, *C. chinensis*, is native to southern China and can reach a height of 37 metres.

9 The *C. jacquemontii* species is the Indian tree hazel native to Northern India, Pakistan and other areas in the Himalayas.

10 Tibetan tree hazel, *C. ferox*, is a very unusual species because it has husks that resemble the burr of a chestnut.

All have edible nuts, but the shells of many of them are extremely thick and difficult to open.

"The European species that we mostly use in breeding has tremendous genetic diversity, yet there are a few things that we would like to bring from the outside," said Mehlenbacher. "These include other sources of Eastern Filbert Blight resistance, the non-suckering growth habit of the tree hazels and extremely early season maturity, for example, the California hazel matures at the end of July or the first week of August (mid to late summer)."

There are also desirable traits such as early flowering. For instance, there are some seedlings from Korea which flower in the second year. Cold hardiness is another desired trait as well as tolerance to calcareous soils, which is important in some growing areas.

Erdogan's research focused on three different aspects, all addressing how these species are related to each other and how they can be used in breeding. "He used three different approaches to answer the same questions. The first approach was to make inter-specific crosses to see which ones crossed readily and which ones did not," said Mehlenbacher. "The success of crosses was expressed as percent cluster set — the ratio of cluster set to flowers pollinated. He found that many inter-specific crosses yielded no cluster set at all, while some crosses set very well at 50 percent cluster set, which is typically found within the European species."

For the nuts produced, Erdogan calculated percent blanks. He also looked at the pollinated flowers under a special microscope to determine if incompatibility was responsible for low set.

Erdogan's second approach was to measure and rate many different characteristics. Erdogan looked at 23 different morphological traits such as husk traits, nut traits, leaf traits, seed germination traits, etc. and five phenological traits which have to do with timing such as

Table 1. Percent cluster set in various hazelnut species crosses.

Female parent	AVE	AME	HET	COR	CAL	SIE	COL	CHI
C.avellana	58.9	35.4	17.4	0.0	0.0	0.1	7.1	0.0
C.americana	40.3	44.6	40.3	2.7	5.1	36.5	3.2	3.4
C.heterophylla	2.6	0.6	0.6	0.0	0.0	0.2	0.5	3.3
C.cornuta	4.2	3.2	3.2	35.8	40.9	49.4	4.0	0.0
C.californica	36.3	21.6	21.6	45.7	44.6	38.4	27.1	10.0
C.sieboldiana	0.0	1.1	1.1	25.1	28.4	47.9	0.6	0.0
C.colurna	20.3	4.8	4.8	0.0	0.7	1.0	29.9	40.0
C.chinensis	41.7	14.3	14.3	0.0	11.6	0.0	60.4	-

Table 2. Frequency of blanks in intra- and inter-specific crosses (3 year average).

Female parent	AVE	AME	HET	COR	CAL	SIE	COL	CHI
C.avellana	18.3	16.3	39.4	66.7	-	50.0	9.4	-
C.americana	26.8	23.4	29.5	80.0	27.6	42.8	56.3	50.0
C.heterophylla	43.2	4.2	42.2	-	-	100.0	100.0	100.0
C.cornuta	100.0	54.3	54.6	28.6	31.7	35.8	28.6	-
C.californica	33.5	54.2	56.4	39.1	17.2	38.1	41.3	64.7
C.sieboldiana	100.0	68.2	82.2	47.5	28.4	22.9	50.0	-
C.colurna	91.6	93.4	97.3	0.0	100.0	100.0	13.5	12.7
C.chinensis	25.8	4.6	-	-	75.0	-	19.5	-

time of pollen shed, time of female receptivity, time of nut maturity and time of budbreak.

The third approach was to look at the same questions, only from a DNA perspective. By looking at the DNA sequences and comparing how similar or different they are, there is an indication of how close some species are to each other. Table 1 shows the percent cluster set for the different crosses. Note that the leafy-husked shrubs and the crosses within that group set fairly well in both directions, C. heterophylla being an exception that didn't set very well.

The second group is the bristle-husked shrubs, and again within this group the species crossed readily, both directions.

The bottom two varieties in Table 1 are tree hazels, which crossed readily with each other, both directions.

"Problems develop when you try to cross a species from one group with a species in a different group," said Mehlenbacher. "And the data in Table I shows that many of the crosses give nothing at all. In some instances there are big reciprocal differences such when you cross the California hazel with the European hazel. If the California hazel was used as the female there was a good set, but if the European hazel was used as the female, nothing was produced."

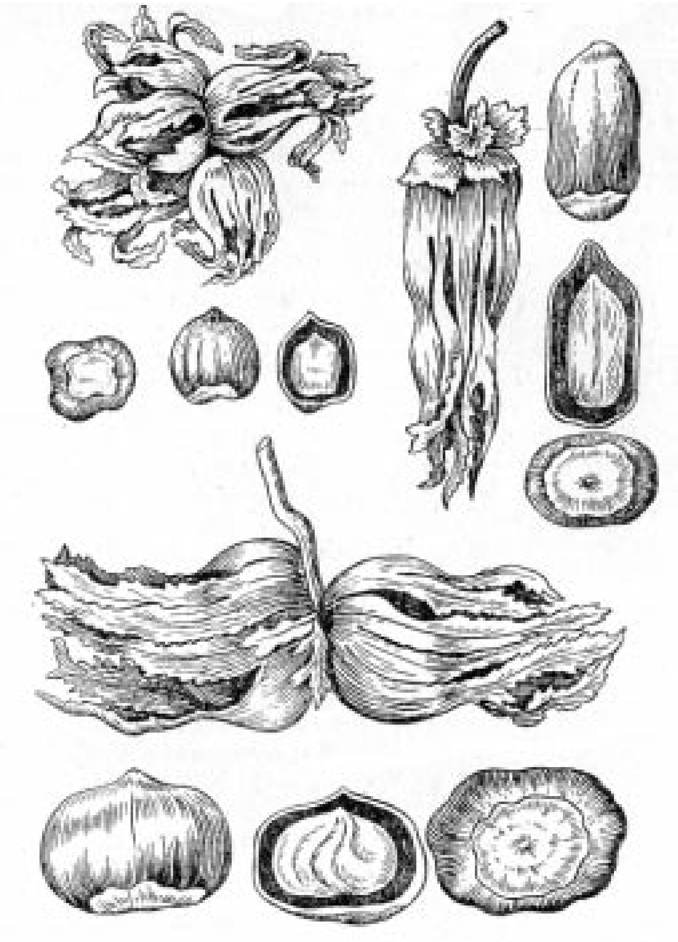
Table 2 reflects the frequency of blanks from the different combinations. Assuming that nuts are produced, the percent blanks ranged from zero to 100 percent. "Again, we found that within a group we typically got between 5 and 50 percent blanks, with 25 percent being typical within a group," said Mehlenbacher. "With other combinations we ended up with 90 to 100 percent blanks, so even though we got set, no kernel developed.

"Part of the reason the crosses failed to set was incompatibility. In a compatible pollination the pollen tube grows down the style, while an incompatible pollination may show up as short tubes growing in random directions," explained Mehlenbacher. "When Erdogan looked at these combinations he found that indeed the pollinations appeared to be the classic appearance of what we see in incompatible pollinations even within *C. avellana*."

Erdogan also found that in certain combinations within all the other species he looked at, some combinations were incompatible, while some were compatible. So it appears that incompatibility is widespread in all these hazelnut species. The conclusions of the inter-specific hybridisations in these groups is that crosses within a group are quite easy, and crosses among groups are difficult, noted Mehlenbacher. First you don't get set; secondly, if you do get set the nuts may be mostly blank, and thirdly there are reciprocal differences that make a big difference in which direction the cross is made.

During this study many combinations of species were made or attempted for the first time. "We have been working with the USDA repository in Corvallis for quite a few years to collect hazelnut material from all over the world. In fact we have the best collection of hazelnut varieties in the world and we use that material in the research," said Mehlenbacher.

One of the successful first-time reported crosses was *C. americana* with *C. sieboldiana*, which gave good set. Another interesting observation was that the California hazel, as a female, can be crossed with virtually every other species, which is quite unusual — making it useful as a possible 'bridge' species in the future. Mehlenbacher explained that a bridge species is one that, if you can't cross species A with species B, you might be able to cross species A with the bridge and then cross that hybrid with species B.



Some varieties of hazelnuts

The morphological data in the experiments showed an interesting germination characteristic among the hazelnut species. All the tree-type hazels showed one type of germination while the shrub species have a different type of germination.

"If you plant beans in your garden, you know that when they germinate you see the seed move as the radical emerges along with the cotyledon and stem. But if you plant Barcelona seed, the seed doesn't move when the radical and shoot tip emerges," reported Mehlenbacher. "We found that all the tree hazels had epigeal germination such as the bean, and the shrub type hazels had the hypogeal-type of germination. This had never been reported before."

The DNA study showed that only 22 of the 666 base pairs in the ITS region showed any variability from one species to another, which made the sequences easy to align and comparisons straightforward. But, the minimal variability also suggests that hazelnuts are relatively recent in its evolution. Because it hasn't evolved over enough time it doesn't show many differences. In other crops, the variability is far greater.

The DNA study agrees with the morphology studies in that the leafy-husked shrubs are grouped together with similarities as are the bristle-husked shrubs and the tree hazels. Also, as expected, the *C. ferox* hazel with the burr-like husk is separated from the other tree hazels.

Mehlenbacher explained how all this information could be used to breed new varieties for the Oregon hazelnut industry. One area is in developing Eastern Filbert Blight (EFB) resistance for the new varieties.

Many of these species are immune to EFB, while others are highly susceptible, such as the Indian tree hazel. We know that a single gene from the 'Gasaway' variety gives a very high level of EFB resistance. "There is a DNA marker closely linked to the Gasaway gene which can allow us to identify seedlings likely to be immune before the seedlings are planted in the field," Mehlenbacher said. By going through the European selections, several new sources of EFB resistance were found. These have started to be used in breeding.

Other species that do offer high resistance or immunity is the *C. americana* species, as it has co-evolved with EFB for several thousand years. The American and European types can be crossed in any direction with good set. Other crosses have been made as well.

Another potential application of the research is in using tree hazels as a source for non-suckering. Harry Lagerstedt, a well-known former OSU hazelnut researcher worked for many years on the release of 'Newberg' and 'Dundee' — reportedly half Turkish tree hazel and half European. A promising combination was using the Chinese tree hazel as the female and the European hazel as the pollen parent, which gave good set and not too many blanks.

There is much more information that can be derived from Erdogan's research. Over time, the information he uncovered will lead to other major discoveries and perhaps the 'near perfect' hazelnut for the industry.

[Based on an article in '<u>Pacific Nut Producer</u>', March 2000].

[Metric conversions by the Tree Crops Centre].

<u>Pacific Nut Producer</u>: A3023.

BITTER ALMONDS —
The case of the tasty but poisonous nut

DAVID KARP §
633b Palms Boulevard, Venice, CA 90291, USA
<dkarp@sprintmail.com>

To meet Paul Schrade, a tall, white-haired 77-year-old with a gently bemused smile, you'd never suspect that he's obsessed with a poisonous nut. Mention the bitter almond, however, and the retired union organizer won't stop talking about how — on a culinary tour of Sicily in 1990 — he fell in love with its powerful, unique flavour, which gives marzipan and almond milk their characteristic taste. Even after he was told that raw bitter almonds contained a form of cyanide and were illegal in the Unites States, Schrade was fascinated.

"I thought, 'European chefs make good use of bitter almonds for cooking and baking — why shouldn't we?'" he says.

Through his second career as a bakery consultant and forager for Campanile restaurant, Schrade sought to spur a revival of the ancient Mediterranean flavouring in California. Undeterred, or perhaps intrigued, by the nut's sinister reputation — spread by mystery tales in which the detective sniffed the odour of bitter almonds on a cyanide victim's breath — he sleuthed relentlessly for sources and information. He learned that most of the original wild species of almonds were bitter, but that, as the nuts came into cultivation thousands of years ago, farmers began concentrating their crops toward sweet types, the kind grown today in California.

A recessive gene causes bitter almond trees to produce in their shoots, leaves and kernels a toxic compound called amygdalin, which serves as a chemical defence against being eaten. When amygdalin is moistened, it splits into edible benzaldehyde, which provides an intense almond aroma and flavour, and deadly hydrocyanic acid, a fast-acting inhibitor of the respiratory system.

The lethal dose of raw bitter almonds depends on the size of the nuts, their concentration of amygdalin and the consumer's sensitivity. But scientists estimate that a 70-kilogram adult might die from eating between 10 and 70 raw nuts, and a child from ingesting just a few.

In any case, although it may be safe for most adults to nibble a raw bitter almond to experience its intense flavour, that would be unpleasant to most people. The nuts are not meant to be eaten as a snack food like regular almonds: They're used as a spice, like nutmeg or cinnamon.

§ Member, WANATCA

Schrade, who studied organic chemistry at Yale, learned that because hydrocyanic acid vanishes into the air when heated, cooking destroys the poison in bitter almonds and allows them to lend their flavour to a wide range of dishes, both traditional and modern.

In the course of his explorations, Schrade found several California chefs eager to cook with bitter almonds. At the centre of this informal network is Tim Woods of Echo restaurant in Fresno, famed for his zealous use of local ingredients.

Since bitter almonds are usually not available commercially, he harvests his nuts from nearby wild and backyard trees, and uses them to add a pleasing bite to the richness of bread pudding with caramel and to stone-fruit cobblers. He also shares his supplies with Sean Lippert, formerly chef of Across the Street in New York, for her bitter almond granita, and with Judy Rodgers of Zuni Cafe in Berkeley and Kim Boyce, pastry chef of Campanile, who both use the nuts to flavour panna cotta and ice cream.

Until recent decades, most Mediterranean almond orchards were grown from seed, and the shuffling of genes resulted in a mix of bitter almond trees among the sweet. Growers liked to keep a few bitter trees around because they helped to pollinize the sweet varieties. The inclusion of bitter nuts gave snackers occasional unpleasant surprises, but they deepened the flavour of marzipan, almond milk and glazes for cakes. In Italy, bitter almond paste was traditionally used to make crisp amaretti cookies, and bitter almond extract flavoured amaretto liqueur. In Greece, bitter almonds are used in soumada, a sweet syrup.

There's little large-scale cultivation of bitter almonds left in Spain and Italy, mostly just scattered trees remain, but it is still possible to buy raw bitter almonds at European specialty markets. Morocco and Iran now lead in commercial production of bitter almonds.

In the United States, the lack of clear information about bitter almonds' legal status has squelched their cultivation, trade and use. No stores regularly stock bitter almonds, so cooks seeking them have had to rely, like Woods, on seedling trees growing wild along streams, roads and railroad tracks.

"I don't know if I should sell them or not," says Bill Fujimoto, owner of Monterey Market in Berkeley, which carries bitter almonds occasionally. "I don't leave them out on the counter. I sell them only when people who know bitter almonds ask me for some." Over the years, Schrade made dozens of inquiries to federal and state health authorities about the legality of bitter almonds, but never received a definitive answer. Recently, however, a friend steered him to a Food and Drug Administration Web site that states, "Because of their toxicity, bitter almonds may not be marketed in the United States for unrestricted use." The agency's regulations do, however, allow almond paste and extract manufacturers to use the nuts as long as their products do not contain more than minute, safe levels of hydrocyanic acid.

The FDA clarified the agency's position recently, saying that it would allow bitter almonds to be shipped interstate to professional chefs and bakers, as long as their dishes were cooked to be nontoxic. But the agency said it would take "appropriate action" against vendors found to be selling bitter almonds to the public in such a way that they could easily be confused with regular almonds. These actions might include issuing a warning, or seizing the product.

The FDA regulates interstate commerce in foodstuffs, but bitter almonds grown and sold within California fall under the jurisdiction of the state's Department of Health Services, which takes a less restrictive approach to retail sales. James Waddell, acting chief of the department's Food and Drug Branch, says that the agency has no specific regulation covering bitter almonds, but that the nuts could be sold in accordance with its rule for bitter apricot kernels, which requires packages to bear labelling stating: "may be toxic; very low quantities may cause reactions." The upshot is, California growers and vendors are permitted to sell properly labelled packages of bitter almonds to California consumers.

This is good news to Rusty Hall, one of Schrade's discoveries, who grows both sweet and bitter almonds, which he sells at farmers markets and by mail order. Virtually all the state's sweet almonds come from vast irrigated orchards of densely planted trees in the Central Valley, but at his ranch near Paso Robles, Hall quixotically tends an ancient orchard that he dry-farms, which he is convinced gives his sweet almonds more concentrated flavour.

On a bright September morning in the middle of harvest, Hall surveyed his widely spaced trees, their roots reaching deep into the rolling hills.

Central Valley farmers harvest mechanically, but Hall and his workers gathered the crop by hand, using long poles and rubber mallets to knock down the almond fruits, which resembled thin-fleshed, split-open apricots, onto tarps.

They carefully avoided half a dozen bitter almond trees, which were flagged with red surveyor's tape tied to their branches. Almond orchards in the area were grafted on almond seedling rootstock, explained Hall, and some of the rootstock, as usual, turned out to be bitter almond. Sometimes the sweet almond graft didn't take, or the scion later died, leaving the bitter rootstock to develop into a tree.

It's not hard to find bitter almond trees in local orchards, he added, but tough to convince a processor to hull and shell the nuts: California sweet almond growers, who harvested 210,000 hectares last year, regard bitter almonds as contaminants. Therefore, said Hall, he'd have to wait until the end of the season to pick and process his bitter almonds separately.

Because of the almond industry's fear of bitter nuts, it seemed impossible that anyone would dare to grow them commercially in California. But a little more than a year ago, Schrade announced triumphantly that he had found such a source: Thomas Vetsch, a Swiss American grower from Bakersfield, had a small planting of 3-year-old bitter almond trees, which were just starting to bear, as a sideline to his 1,200 acres of sweet almonds.

On a blustery day last March, with his almond orchards in full bloom, Vetsch gave instructions to a beekeeper and shared his passion for almonds.

"Just look at this," he said, gesturing excitedly at the sea of white blossoms. "This is the glory of the world, the wonderful sweet fragrance, the bees flying around. Hear that buzz? That's what you want to hear: strong bees," he said, his eyes gleaming.

Vetsch and his wife, Kim, had fallen in love under an almond tree, he said.

The almond project was their dream. In addition to selling bulk almonds commercially, they have a smaller venture, Mandelin, that manufactures almond pastes. A perfectionist, he had originally planted some bitter almonds so as to be able to control all the ingredients for the pastes, normally made with imported oil of bitter almond.

But when he was asked to show a visitor his bitter almond trees, his expression darkened. At a recent almond industry conference, rumours that someone in Kern County was growing bitter almonds had caused a sensation.

Soon thereafter, Vetsch had fired up the chain saws.

"It's over. It's history. I have no more bitter almonds," he said vehemently, pointing to a bulldozed section with a pile of uprooted trees.

"In Europe they love bitter almonds, but they will never be grown here.

Americans are so sue-crazy — if someone feels a little off, the first thing they do is call a lawyer. I can't put the whole farm in jeopardy." Vetsch said he hadn't given up his quest for European-style, full-flavoured almonds, however. At his office and factory in Bakersfield, he offered a taste of nuts higher in oil and richer in flavour than American almonds.

"That's as close to bitter as it gets, but with no poison," he said. "We use it in our almond pastes." Asked to name the variety, he said, "What? Do you think that I'll tell my secrets?" When told of the trees' demise, Schrade was disappointed but philosophical.

It will take further work to remove the stigma of bitter almonds, he reflected.

As much as he loves the flavour the nuts provide, he said, "Sometimes when I'm on the treadmill at the gym and I feel a bit peaked, I wonder: 'Am I getting old? Or is it the bitter almonds?'"

****

What to Use When You Can't Get the Real Thing

Since bitter almonds are difficult or impossible to obtain in the United States, home cooks, professional chefs and industrial users have long resorted to alternative sources for intense almond flavour.

Apricot and peach kernels, easy enough to obtain from fresh fruits by cracking open the pits (put them in a kitchen towel and hit them with a hammer), can substitute for bitter almonds, though they have less amygdalin and thus less flavour. Generations of home canners have used one or two kernels to add a heightened flavour when cooking peach, apricot and cherry jam.

"The flavours are close enough," says Tim Woods of Echo restaurant in Fresno.

"I prefer bitter almonds, however, because the apricot kernels often have a musty taste."

China exports bitter nuts which are often called almonds but are botanically apricot kernels. The fruits, closely related to almonds, are grown primarily for their seeds, not for their flesh. To complicate matters, China and Central Asian countries also produce sweet apricot kernels, which can be eaten like normal almonds. Chinese bitter apricot kernels are available at some ethnic markets in the United States (often without warnings of their toxicity, in violation of state and federal regulations), but before buying it's important to ask whether the kernels are bitter or sweet. The bitter kernels are often called "north" almonds, and the sweet kernels, "south" almonds. All bitter nuts, of course, must be cooked to remove the cyanide.

Peach leaves macerated in hot water may also be used for bitter almond flavour.

The most common sources of bitter almond taste, however, are almond extracts, which are distilled to be free of cyanide. "Pure" almond extract should contain natural oil of bitter almond, a colourless fluid, along with water and alcohol. "Natural" extract usually is flavoured with benzaldehyde made from cassia, a relative of cinnamon. "Imitation" extract uses synthetic benzaldehyde, which is manufactured from a petrochemical.

Although oil of bitter almond can be pressed from bitter almonds, apricot kernels and other fruit kernels containing amygdalin (such as those from peaches, plums or cherries), true bitter almonds almost never are used.

Apricot kernels yield more oil and, being byproducts of the fruit industry, are cheaper.

It takes 95 kg of kernels to make 100 g of bitter almond oil, so the natural product is very expensive compared to the synthetic benzaldehyde in "imitation" almond extract. Many cooks say that pure and natural almond extracts have a more rounded taste than the imitation product, but the flavouring in all three forms consists almost entirely of benzaldehyde, and chemists must use sophisticated analytical tests to tell the difference.

There is thus considerable incentive for manufacturers to substitute the cheaper products, and several industry sources claim that most of what is sold as oil of bitter almond in the United States is actually from cassia or even synthetic.

"I'd question whether there's any of the real stuff around any more," said Kim Bleimann, president of Berje Inc., an importer of essential oils based in Bloomfield, N.J.

In response, Laurie Harrsen, a spokeswoman for McCormick, the nation's leading extract manufacturer, said: "The oil of bitter almond in McCormick's pure almond extract is derived from apricot kernels, in accordance with FDA regulations."

[Metric conversions by the Tree Crops Centre]

CAROB GENETIC RESOURCES IN THE
BALEARIC ISLANDS OF THE MEDITERRANEAN

I. BATLLE & J. TOUS
Institut de Recerca i Tecnologia Agroalimentaries (IRTA)
Centre de Mas Bove, Departament d'Arboricultura Mediterrania. Apartat 415, 43280 Reus, Spain
<ignasi.batlle@irta.es>, <Joan.Tous@irta.es>

J. RALLO
Conselleria d'Agricultura, Comerc i Industria.
Govern Balear, C/ Foners 10,
07006 Palma de Mallorca, Spain

Introduction

The carob (*Ceratonia siliqua* L.) is an evergreen tree native to the eastern Mediterranean region and has been introduced in most mild areas. Wild and naturalized carobs are distributed in more or less the same geographic and climatic belt as the cultivated ones.

In the Iberian Peninsula, forms of spontaneous carobs are particularly common at low altitudes along the Mediterranean coast, southwest Spain, southern Portugal and the Balearic Islands (Batlle and Tous, 1997). It is important to explore the native carob genetic resources of each carob growing region, as knowledge of existing cultivars is still poor (Batlle, 1997). The islands, due to their isolated conditions, are particularly interesting for survey.

The carob is a dioecious species with some hermaphroditic forms; thus male, female and hermaphrodite flowers are generally borne on different trees. The carob grows as sclerophyllous shrub or tree up to 10 m high, with a broad semi-spherical crown and a thick trunk and sturdy branches (Batlle and Tous, 1997). The carob tree thrives on poor, calcareous and dry soils, on which it prevents erosion. It can only withstand light frost; temperatures below -7°C can damage trees, especially young ones (Tous and Batlle, 1990). The carob tree, although leguminous, is unable to fix atmospheric nitrogen (Martins-Loucao and Rodriguez-Barrueco, 1982).

Traditionally, the pulp of the pod was used for livestock feed; the seeds were discarded (or used for weighing jewels and drugs as carats!). Thus growers have been selecting towards high pulp content. However, over the last decades the most profitable part of the pod has become the seed for extracting a gum to make a stabilizer and thickener used by the food and pet food

Figure 1. Carob and almond orchard at Ibiza, Spain

industries. In addition carob powder made from ground pods is used as a healthy substitute for cocoa and in the production of pharmaceuticals.

In the Balearic Islands, the main Spanish Mediterranean group of islands (5,014 km^2) there are both mainly cultivated and also wild types of carob trees. There are around 12,000 carob cultivated hectares and some 50,000 scattered trees (MAPA, 1997). The annual production of carob pods is estimated on 25,000 t, variable depending on years, and seems underestimated due to some direct consumption by sheep and goats. Some cultivars from the Balearic Islands are reported to yield 16% of seeds (Batlle and Tous, 1997). We report here our collecting activities and findings.

Materials and methods

The methodology followed was similar to that used in early carob surveys made in Catalonia (Batlle and Tous, 1990) and Andalusia (Batlle and Tous, 1994). The objectives of the carob survey in the Balearic Islands were:

- To establish and delineate growing areas of the main cultivars
- To identify existing cultivars, discarding synonyms and misnames
- To identify outstanding types of high seed yield, low alternate bearing, low susceptibility to *Oidium*, uniform ripening and easy pod dropping
- To introduce the selected types at IRTA's carob gene bank

The final aim of this project was to obtain material with particular characteristics, rather than to conserve the genetic diversity of this crop, to offer to the producing and nursery sectors, cultivars and types with high seed yield (more than 12% yield).

During a week in September 1998 we carried out a survey of carob germplasm in the major islands of Majorca and Ibiza. We first identified the main producing areas of Majorca and Ibiza, from previous information (Rullan and Estelrich, 1882; Caja et al., 1984), and established an itinerary. Our survey was carried out in September, which is the period when carob ripening and flowering overlap. Pods are ready for harvest and so can be assessed, and flowers show the sex of each tree and the potential crop for the following year. We travelled by car, some 1,000 km around both islands. It was planned to collect and introduce interesting individual clones by budding onto seedlings in April 1999. Some 6 selected types were to be introduced at IRTA's carob gene bank.

Results and comments

Carob growing in Majorca and Ibiza is well spread over both islands as most of the sites have mild conditions. Orchards are only missing, above 500 m above sea level, from the Tramontana range along the western part of Majorca. Only small numbers of wild carobs are present in other islands of the archipelago.

Annual mean temperature during the year varies between 16° C and 17° C in Majorca and is around 17.5 °C in Ibiza (Elias and Ruiz, 1977). Average annual rainfall in the main carob growing area ranges from less than 400 mm to 900 mm in Majorca and from 300 mm to 500 mm in Ibiza (Elias and Ruiz, 1977). Carobs are frequently found growing with almond trees (Fig.1) and also with fig and olive trees (this last association is more often found in Ibiza).

While the carob is a very drought resistant species and grows well on unirrigated lands, its production of pods is related to the amount of effective rainfall, and thus production on both islands is very variable. In some zones, it is common to find sheep and goats feeding directly on the carob groves. Harvesting, which is a major cost in carob production, is carried out manually using long poles to knock down ripe pods and collecting them on fibre nets laid out under the trees.

Commercially, the two main carob pod parts are (by weight): pulp (90%) and seed (10%). Variation in the proportion of both pod constituents is wide and raises the possibility of selecting high seed-yielding cultivars. This is also used as the basis for the commercial classification of carob pods of both islands into 4 geographical areas, depending on origin and pod trait characteristics (mainly seed yield):

"Mountain" (high >13%), "Plain" (medium, 912%), "Soller" (low < 9%) and "Ibiza" (medium-high, 9-13%).

Traditionally, the main selection aims by growers have been large pod size and high pulp and sugar content. It is known that pulp and seed content show a negative correlation. Female plants always have been selected in preference to the hermaphrodites as they are better pod

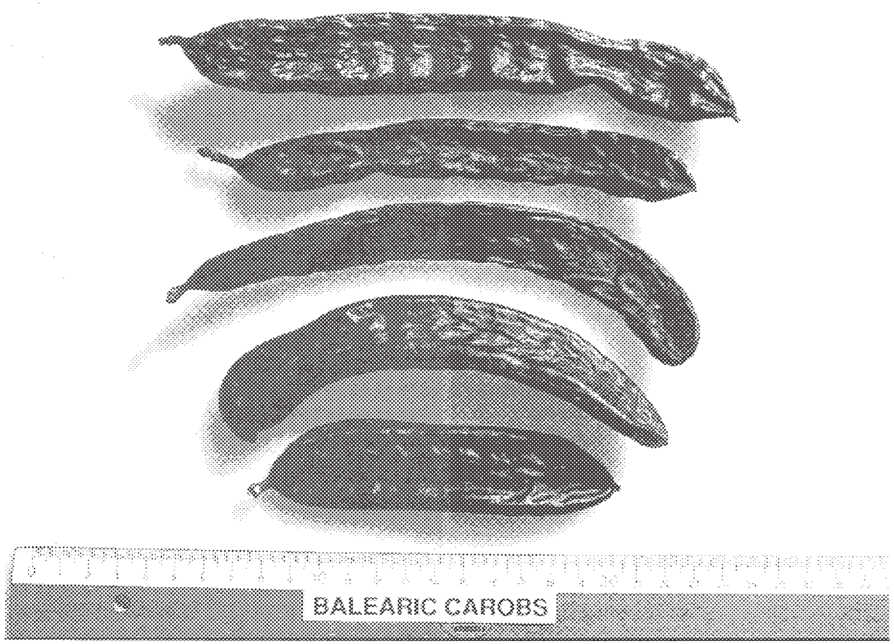


Figure 2. Diversity in carob pods from the Balearic Islands

bearers (Batlle and Tous, 1997). Within the cultivated germplasm of the Balearic Islands, wide variation of pod size and shape was found (Fig. 2). The most likely origin of cultivars is as chance seedlings.

The most interesting features of the carob cultivars in the Balearic Islands are: high number (23: 17 female and 6 hermaphrodite), antiquity, and limited diffusion. Most cultivars found were already cultivated in 1800. In addition, cultivars show a limited distribution and are only grown close to their original area. Currently, there is a trend to reduce the number of cultivars and to propagate only the highest seed-yielding, like 'Bugadera' and 'Duraio' in Majorca and 'Uraiona' in Ibiza (although records of seed production per hectare, of prime importance, are largely unknown).

During the survey a high number of hermaphrodite types were observed, a higher number than in other producing regions of the Iberian Peninsula. A main cultivar in Majorca like 'Bugadera' shows often perfect flowers. In this cultivar, sex expression seems to be related to environmental conditions. A similar feature occurs in Ibiza with the hermaphrodite 'Banyeta'. The cultivation of hermaphrodite cultivars has only been found before with 'Ramillete' in Murcia, another Spanish growing area, as mainly female cultivars are grown (Batlle and Tous, 1997).

Apart from the frequent presence of hermaphrodites, orchard pollination is assured by males which are isolated seedling trees or branches left on rootstocks after budding female

cultivars. These are found in the orchards or on their edges. Two important non-fruiting male types were observed and locally named — after their anther colour — as 'Red' and 'Yellow'. As in other regions, it appears that blooming of 'Red' males is more extended than that of 'Yellow' males (Batlle and Tous, 1997).

Majorca

During the survey, 20 female and 3 hermaphrodite names were listed. Only 16 of the female cultivars are different and the rest are synonyms ('Costella' syn. 'Costella d'Ase', 'De la Mel' syn. 'Negrillo', 'Del Cabull' syn. 'Del Remei'). The cultivars 'Rotge', grown in the north, and 'Vermella', grown in the south, are different. A number of cultivars as well as local types are grown in very small areas. Main cultivars like 'Bugadera', 'Costella', 'Duraio' and 'De la Mel' are grown mainly in the East, the West, the Centre and the Palma plain respectively. There were also found a number or very local ones like 'Denia', 'Fua de Rabo', 'Punyal', 'Toledo' and 'Valencia'. Some recently selected promising local types like 'D'en Pau' from Santa Maria del Cami (which is highly productive, does not drop leaves under stress, and shows low susceptibility to *Oidium)* in inland Majorca, were also identified. This cultivar is now being propagated by growers outside its original area. In addition, it was interesting to note some special uses of cultivars like 'Vermella' from the area of Llucmajor, which produces pods with high content of rose-coloured pulp and was very much in demand back in the 1950s during the cocoa crisis, due to its good pulp characteristics when roasted and used as cocoa substitute. 'Vermella' pods stand strong winds and ripens late (J. Marti, personal communication).

Cultivars were classified into 3 groups in importance; as main: 'Bugadera', 'Duraio', and 'De la Mel'; secondary: 'Costella', 'Mollar', 'Negra', 'Pic d'Abella', 'Rotge', 'Vera' and 'Vermella'; and local types: 'Fua de Rabo', 'Mausulin', 'Pasta Negra'; and 'Florite', 'Manflorida' and 'Lloseta' (hermaphrodites).

Ibiza

During the survey 8 female cultivar names and 2 hermaphrodites were recorded. Of the female types, only 5 were distinct cultivars, as some were synonyms ('Panesca' syn. 'Rodona' or 'Rodo') and a few were mistakes ('Uraiona' or 'Uraio' from Ibiza is different from 'Duraiona' or 'Duraio' from Majorca). The name 'Espana' groups a number of different types. Cultivars were classified into 3 groups, regarding their importance, as main cultivars: 'Panesca' and ''Boval'; secondary 'Fina' and 'Uraiona'; and local types: 'Banyeta' and 'Rojal' (hermaphrodites).

Acknowledgements

This work has been funded by the Instituto Nacional de Investigacion y Tecnologia Agraria y Alimentaria (I N IA) of the Spanish Ministry of Agriculture, Fisheries and Food through the Project (RF98021). We are indebted to the Govern Balear for providing a car. We are grateful to many growers and kibblers for their help.

References

Battle, I. 1997. *Current situation and possibilities of development of the carob tree (Ceratonia siliqua L) in the Mediterranean region*. Nucis 6: 33-38.

Batlle, I.; J. Tous. 1990. *Cultivares autoctonos de algarrobo (Ceratonia siliqua L.) en Cataluna*. Investigacion Agraria. vol. 5 (2): 223-238.

Batlle, I.; J. Tous. 1994. *Carob germplasm in Andalusia*. Nucis 2: 10-11.

Batlle, l.; J. Tous. 1997. *Carob tree. Ceratonia siliqua L*. Promoting the conservation and use of underutilized and neglected crops. 17. Institute of Plant Genetics and Crop Plant Research, Gatersleben /International Plant Genetic Resources Institute, Rome, Italy. 92 pp.

Caja, G., R. Casanova, A. Cabot. 1984. *El Algarrobo (Ceratonia siliqua, L.): su cultivo y posibilidades agropecuarias en Baleares*. Avances de resultados. Caja de Ahorros "Sa Nostra". Palma de Mallorca, 103 pages (typeset copy).

Elias, F.; L, Ruiz. 1977. *Agroclimatologia de Espana*. Instituto Nacional de Investigaciones Agrarias. Cuaderno INIA 7. Ministerio de Agricultura. Madrid.

Martins-Loucao, M.A.; C. Rodriguez-Barrueco. 1982. *Studies in nitrogenase activity of carob (Ceratonia siliqua L.) callus cultures associated with Rhizobium*. Proceedings. V International Congress Plant Tissue Culture. Tokyo. 671-672.

MAPA. 1997. Ministerio de Agricultura, Pesca y Alimentacion. *Anuario de Estadistica Agraria*. Ed. Secretaria General Tecnica. Madrid, Espana.

Rullan, J. y P. Estelrich. 1882. *Memoria sobre el algarrobo y su cultivo en Mallorca*. Imprenta y libreria de P.J. Gelabert Imprenta. Palma de Mallorca, Espana. 100 pp

Tous, J.; I. Batlle. 1990. *El algarrobo*. Ed. Mundi-Prensa. Madrid, 102 pp.

[Based on an article in FAO - Nucis-Newsletter, Number 7 December 1998]

IRTA: A2026

Nucis-Newsletter: A3287

THE DIVERSITY AND ORIGINS OF MACADAMIA CULTIVARS

C PEACE[1,2], C HARDNER[1], AHD BROWN[3], K O'CONNOR[1], V VITHANAGE[1], C TURNBULL[4], AND BJ CARROLL[2]

Summary

This article reports on a comprehensive survey of macadamia cultivars and wild trees using DNA typing. Cultivars are assigned to specific genepools, which may help in understanding patterns of cultivar performance. Species status of cultivars (whether integrifolia, tetraphylla, or hybrid) is the major determinant of genepool differences. However, determining whether a cultivar is a pure species or a hybrid no longer has to rely on ambiguous leaf, flower, and nut characters. The species status of cultivars is now resolved, as the approximate proportion of each species in any tree can be quantified using new diagnostic DNA markers.

Species status may also help explain field performance. Grouping of integrifolia cultivars appears to be a result of their natural origins. Surprisingly, most integrifolia cultivars appear to have come from the northern-most parts of integrifolia's natural range (Mt Bauple to Amamoor/Imbil). This was also identified as the region containing the least genetic diversity. Other regions seem to be largely unexploited. The recently established National Macadamia Germplasm Collection has added over 50% more genetic diversity to what was previously accessible. Breeders are now in an excellent position to capitalise on this information, to ensure a profitable and sustainable future for the Australian industry.

Introduction

Two species of macadamia – *Macadamia integrifolia* and *M. tetraphylla* – and their hybrids are cultivated, though the world industry relies primarily on integrifolia. Information on the genetic diversity and natural origins of the world's macadamia cultivars is very limited. Cultivars are only grouped according to what species they appear to be morphologically, and where and when they were selected, though even this general information can be ambiguous for some cultivars. Overall, such a classification system is haphazard. The relationships amongst cultivars of the world are mostly unknown. Historical records are scarce and can be

[1] CSIRO Plant Industry, Meiers Rd, Indooroopilly, 4067 Australia

[2] School of Molecular and Microbial Sciences/School of Land and Food Sciences/Department of Botany, University of Queensland, St Lucia, 4067, Australia

[3] CSIRO Plant Industry, Black Mountain, 2601, Australia

[4] Imperial College at Wye, University of London, Wye, Ashford, Kent, TN25 5AH, UK

misleading as to which rainforests the first seeds were taken from, where resulting trees were later distributed, and what cultivars were developed from them. It is unclear as to how much exchange and mixing of germplasm has taken place in the past.

Selection and breeding programs throughout macadamia's cultivation history have had little understanding of the genetic relationships amongst the material assessed. Similarly, the many research projects that have studied the performance of cultivars under various treatments have attempted to choose a diverse range of cultivars, yet researchers have had little information on which to base such decisions. This fundamental information is important, yet overlooked, for macadamia research.

For most crops of the world, it is too late to gain more than very broad generalisations of what region their wild progenitors originated from, and when and where humans cultivated, dispersed, and changed the crop.

However, unlike most of these other crops, macadamia's domestication history is relatively short – just 150 years – and modern cultivars are only a handful of generations removed from the wild. Modern DNA typing technology can uncover many of the clues that remain, and allow the story of macadamia to be pieced together.

New Insights From Dna Analysis

Table 1 summarises many of the new insights gained into the diversity and origins of macadamia cultivars. Seven cultivar genepools are described in terms of the cultivars they contain, their species status, their relationship to natural regions, the genetic diversity they contain, and the relationships between them. All cultivated trees are referred to as "cultivars" in this paper, though technically a cultivar is an officially named and released variety rather than just a selection from a breeding program.

Cultivar genepools

The cultivar family tree (Table 1, first column) defines seven cultivar genepools, showing the average diversity between cultivars within each genepool, and the diversity between the genepools. Almost eighty cultivars from a variety of selection origins were surveyed to produce this family tree, and these are listed underneath Table 1. In general, cultivars that appear in the field to be integrifolia are at the top of the family tree, with hybrids further down and tetraphyllas at the bottom.

Almost all of the Hawaiian cultivars are within genepools 1 and 2, which also contain some Israeli cultivars (thought to be derived from Hawaiian seed), and a few Australian cultivars of independent selection origin. Genepools 3 and 4 contain mainly Australian cultivars that are usually classed as integrifolias. Genepools 5 and 6 contain mainly Australian hybrid cultivars, with genepool 6 representing many of the hybrids that were part of or derived from Norm Greber's selection program. Genepool 7 contains hybrids and tetraphyllas selected in Australia and South Africa.

Species status of cultivars

The recently established National Macadamia Germplasm Collection (NMGC) was also surveyed with the same DNA tests as the cultivars. The NMGC sampled almost 400 trees from approximately 75 populations across the natural range of *M. integrifolia*. *M. tetraphylla*, and their wild relative, *M. ternifolia*. Over 120 DNA markers were identified that were associated with one of the three species.

These diagnostic species markers allowed calculations to be made of the proportion of each species within each cultivar. This means that species status is no longer an ambiguous classification based on a few field characteristics. The range of species compositions and the median value for each cultivar genepool (Table 1, columns 3 and 4) show a general trend of decreasing integrifolia content from the top of the table to the bottom. This is consistent with tree appearance in the field.

However, many cultivars believed to be pure species were found to actually contain a small amount of the other species. Hybrids (individuals containing both species) were identified all along the scale from integrifolia to tetraphylla. Further research is required to determine what beneficial or detrimental effects the various tetraphylla contents might have on cultivar performance.

A very unusual hybrid is the later-generation Hawaiian selection 791, also known as "Fuji" and popular in South Africa. This was the only cultivated tree found to have ternifolia in it (around 45%, as well as 5% tetraphylla and 50% integrifolia). 791 has several traits that may be derived from its ternifolia heritage, including small tree stature, precocity, high kernel recovery, and the kernel disorder called "791 spot", but is apparently without the bitterness normally associated with kernels of wild ternifolias.

This highlights some of the benefits that can be gained by incorporation of macadamia's wild relatives into elite genetic backgrounds, particularly if accompanied by stringent screening against undesirable traits. Using ternifolia in macadamia breeding has previously been considered, but it wasn't realised that the Hawaiian breeding program had (probably accidentally) already done so.

Natural origins of cultivars

A family tree constructed for the wild populations of the NMGC (results not shown) identified several major geographical regions for each species, representing natural genepools. Comparing DNA profiles of cultivars and wild trees revealed the likely natural origins for many cultivars (Table 1, column 5). Surprisingly, most integrifolia cultivars, including just about all of the Hawaiian and Australian integrifolias, appear to have come from the northern-most parts of integrifolia's native range (Mt Bauple and Amamoor/Imbil regions).

These regions were also identified as having the least genetic diversity between their populations for integrifolia, and because of this, it is difficult to distinguish between them when determining cultivar origins. Wild integrifolias in the Mt Bauple and Brisbane regions were the closest to major settlements in the latter part of the 1800s, and with more exposure to human scrutiny, are thought to have supplied the seed for the early plantings (Ian McConachie, personal communication).

The two introductions of integrifolia to Hawaii in the late 1800s, on which Hawaiian cultivars are based, were supposed to be from these opposite ends of integrifolia's native range. According to the extensive archives of Ian McConachie, while William Purvis took seed from the Mt Bauple region to Hawaii in 1882, Capt. Robert Jordan took seed from Pimpama, south of Brisbane, to Hawaii about ten years later. The new DNA evidence presented here suggests that the Pimpama trees were actually planted, sourced originally from the northern integrifolia region.

The only pure integrifolias that appear to be derived from closer to Brisbane, where greater wild genetic diversity exists, are Daddow and H2 of genepool 4. Some hybrid cultivars of the other genepools may also have integrifolia germplasm from this region – Beaumont is an example of such. All hybrid cultivars were probably created artificially in cultivation - there is little or no evidence for any hybrid cultivar having come from the natural hybrid zone in the Gold Coast hinterland (where the ranges of the two species overlap).

Most tetraphylla cultivars, and South African hybrid cultivars with a large tetraphylla component, appear to be derived from tetraphyllas in the southern half of that species' range, in particular the areas south east of Lismore and near Mullumbimby. Historical records suggest the same. The world's first macadamia orchard (at Rous Mill, south west of Alstonville, NSW), based on local tetraphyllas, supplied later nurseries with most of their tetraphylla germplasm (Ian McConachie, personal communication). Tim Trochoulias selected the Australian cultivars Tanya and Melina from this southern region.

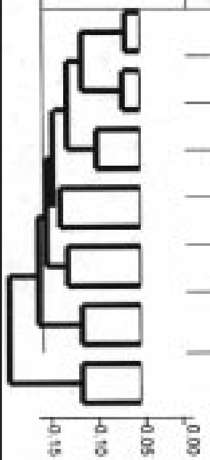
The rest of the cultivars surveyed are probably the result of mixing between natural genepools in cultivation. It is more difficult to determine which specific regions have contributed to these, though the northern-most integrifolia and southern-most tetraphylla regions again seem to be the ones involved.

The common natural origin for so many cultivars, despite integrifolias being developed supposedly independently in Australia and Hawaii, has interesting implications. The northern integrifolia region might contain more of the field traits desired by the past and current industry.

Alternatively, the germplasm from the two selection sources may not be so independent. The early Hawaiian introductions may have been taken from the same cultivated germplasm that went on to form the basis of Australian selections.

Superior trees may have arisen from it in both countries because the germplasm underwent a couple of generations of genetic improvement in cultivation, rather than because of any inherent superiority of the material. Whatever the cause, it highlights that the germplasm of other natural integrifolia regions remains relatively undeveloped.

Table 1: Genetic diversity and natural origins of macadamia cultivars, as determined by DNA typing. Int = integrifolia, Tet = tetraphylla, NMGC = National Macadamia Germplasm Collection. [a] Depth of genepool boxes represents average genetic diversity between cultivars within genepool. [b] Complement is % tetraphylla eg 85%Int = 15%Tet. [c] Calculation includes other markers not assigned specifically to Int or Tet.



Cultivar family tree[a]	Gene-pool	Species status (%Int[b])		Likely region of natural origin	Proportion of NMGC diversity (%)		
		range	median		Int	Tet	both[c]
	1	90-100	100	Mt Bauple and/or Amamoor/Imbil	40	2	20
	2	90-100	100	As above	25	2	15
	3	85-100	90	As above, and Mixed	40	10	25
	4	85-100	90	Brisbane north, and Mixed	60	10	30
	5	40-90	55	Mixed	40	40	35
	6	45-85	70	Mixed	35	20	25
	7	0-50	15	Southern half of Tet range	30	45	35
				Total:	80	60	65

Cultivars included in each genepool are listed below, according to selection origin (**bold** = Hawaiian cultivars; **bold and underlined** = Australian cultivars; standard font = South African cultivars; *italicised and underlined* = Californian cultivars; *italicised* = Israeli cultivars):

Genepool 1: **246, 294, 333, 508, 762, 781, 783, 789, 790, 792, 794, 800, 804, 807, 814, 816, 828, 835, 836, 837, 842, 849, 856,** T7, *A9/9, A2/27, Yonik,* **Mac 2/5, Fernleigh special**

Genepool 2: **344, 660, 741, 772, Heilscher, Own Choice, Release**

Genepool 3: **K100, Kopp, Mason 97, NG13, NG18, Own Venture, Seedling 51, Teddington,** D1

Genepool 4: **791, Daddow, H2, Probert,** DT3, *Faulkner*

Genepool 5: **705, A268, Beaumont, L68, NG3, NG4, NG7, NG8,** Nelmak 26

Genepool 6: A4, A16, A104, A199, A232, Greber Hybrid, L35, NRG, Renown

Genepool 7: **Queen Anne, Young 1, Melina, Tanya,** Nelmak 1, R14, W148, W266

Diversity present in cultivation

The proportion of the integrifolia and tetraphylla genetic diversity of the NMGC captured by each of the cultivar genepools (Table 1, columns 6-8) basically reflects the average genetic diversity within each genepool as shown in the depths of the boxes in the family tree. The values were calculated as the proportion of variable markers in the genepools to those in the whole NMGC. Genepools 1 and 2 contain the least amount of diversity, confirming suspicions that Hawaiian cultivars are very closely related to each other and derived from a narrow genetic base.

The separate natural origin of Daddow and H2 to other integrifolias contributes much diversity to genepool 4, as does the low level of tetraphylla for some cultivars in genepools 3 and 4. Australian cultivars are found in every genepool, confirming the widely held belief that cultivars from this country have the greatest genetic diversity. They contain almost double the integrifolia diversity of all Hawaiian cultivars, and many times more for tetraphylla.

Overall, macadamia cultivars capture about two-thirds of the total diversity of integrifolia and tetraphylla in the NMGC, with more integrifolia than tetraphylla represented. Another way to look at this is that the NMGC has added 50% more genetic diversity to what was previously tied up in cultivars. If the third species, ternifolia, is included in the assessment, the NMGC has 75% more diversity than the cultivars.

So Australian breeders now have access to a massive germplasm base for future improvement of the crop. Of course there may be more diversity remaining in wild populations that the NMGC missed, and the DNA data already gathered can be used to identify which regions could be targeted for maximum benefit.

The future of macadamia cultivars?

Undoubtedly, many useful new genes lie as yet unexploited in the NMGC and remaining wild populations. That many cultivar genepools directly reflect natural genepools indicates there has been little mixing between natural genepools, and so many potentially superior gene combinations remain untested. Much genetic diversity remains unexploited for integrifolia, a positive situation for the world macadamia industry.

Yet there are actually four readily-intercrossed macadamia species – integrifolia, tetraphylla, ternifolia, and the very rare jansenii – each with considerable genetic diversity. Some of the attributes of the species are already known, others will one day be discovered. Macadamia improvement can turn to all of these wild genetic resources.

For other crops, breeders are often reluctant to introduce germplasm from related wild species, or even wild material from the same species, for fear of disrupting their fine-tuned, elite cultivars that have resulted from hundreds of generations of breeding. But for macadamia, the very few generations of selection that have transpired means that today's cultivars are little different to wild trees. Go back no more than six generations from modern cultivars and all macadamia trees were wild. A grandparent of the high performing cultivars A4 and A16 was a wild integrifolia growing by a creek at Amamoor. Another grandparent was probably a pure tetraphylla, which may well have contributed useful traits to A4 and A16 such as their precocity. A striking case is 791, which passed through the stringent Hawaiian selection program, and one of its parents was very likely a ternifolia with no selection performed on it at all.

So wild germplasm of any of the species has been, and can be, readily incorporated into modern cultivars and significant gains made for specific traits. Most cultivars of the future will probably be a mix of the best features of each species. The need to boost yield per hectare, improve kernel quality, combat pests and diseases, extend the climatic range of macadamia production, and the diversification of markets for macadamia products will drive the utilisation of a wide range of macadamia germplasm.

Conclusions

This DNA typing research has provided key information on how much genetic diversity we have for macadamia, and where it is located. The cultivar genepool information provides a basis for understanding patterns of cultivar performance. The quantification of species status and deduction of natural origins helps in understanding the reasons for the arrangement of the cultivar genepools, and may also help explain cultivar performance.

With the small base of germplasm relied on for most modern cultivars, the short period of domestication for the crop, and the ease of hybridisation between the southern macadamia species of Australia, the potential gains through conventional breeding methods are enormous. In future research, the DNA marker information will be combined with performance data, putting the Australian industry in an excellent position to take full advantage of our natural resource.

Acknowledgements

This research was carried out as part of CP's PhD studies, supported by an Australian Postgraduate Award through the University of Queensland, and a CSIRO Plant Industry Grant. The authors gratefully acknowledge the efforts of Dr Julia Playford in her role as early project leader of the NMGC, and Steve Falconer who made the field collections and made valuable observations of wild macadamia. Prof Peter Allan of the University of Natal, South Africa, kindly provided leaf samples for most of the South African selections surveyed here. Thanks are due to Dr Cameron McConchie, Ian McConachie, Henry Bell, and Prof Peter Allan for constructive and enlightening discussions.

[Based on a paper published in the Australian Macadamia Society 2001 Conference Report].

Australian Macadamia Society: A1055.

PROPERTIES AND MANUFACTURE OF VIRGIN SOILS

BRUCE COCKROFT
Shepparton Victoria 3630

Introduction

We all know that virgin soils are the most productive. Since the aim of our orchard soils research is to improve our soils to gain real increases in yields, it is logical that finding out how to develop virgin soils is the way to go. This article is about virgin soils — why they are so productive, why they lose this when farmed, their properties, and our attempts to manufacture virgin-type soil out of our normal orchard soils that are hard and difficult for tree roots. This research is funded by Ardmona Foods Ltd and HRDC [now Horticulture Australia].

Description

In the field, virgin soils are easily recognisable because they are loose, very soft, light, easily broken up into aggregates, the aggregates are rounded and porous, and the soil has an obvious abundance of organic matter fragments. Under the microscope, the aggregates of virgin soil look very porous, a drop of water placed on the surface remains spherical, the water penetrates the aggregate surface slowly, the aggregate does not break apart when dropped into water, it retains considerable strength after becoming saturated, and when crushed it is found to contain a lot of fine grass roots and threads of fungal hyphae.

Orchard soils, on the other hand, are compact, hard, heavy, break up into clods, clods and fragments are angular; under the microscope the fragments appear angular and non-porous, water soaks in rapidly, the fragment tends to collapse in water and contains no fine roots or hyphae. In virgin soils, it is these structure properties that are important to develop rather than nutrients, water and aeration; orchardists provide the latter by fertilisers, irrigation and drainage.

There are two features of virgin soils that are easily the most important to the fruit tree: 1) the very high stability of the aggregates, which do not coalesce together to form a hard mass; and 2) the very high porosity of the aggregates, in the mesopore range, where water is stored for the tree and from where the water is conducted rapidly to the root surface as fast as the tree wants it.

Figure 1 shows the kind of soil we are aiming at. This soil is not a true virgin soil but has all the properties of a virgin soil. It comes from the W6 pear block of Nethersoles' orchard and is quite rare. The soil has not been cultivated for more than 20 years yet remains loose, soft and porous. Recently I measured the amount of tree root in this soil and compared it with twenty district orchards with normal hard, compact soil. Normal soils contain one centimetre of tree root length per cubic centimetre of surface soil. The W6 orchard contains an average

Fig. 1. A soil with good structure due to high organic matter and roots

Fig. 2 A soil with poor structure due to low organic matter and few roots

of fifteen and as high as thirty. The soil in this block of trees is quite exceptional — all four surrounding blocks have normal hard soil. We do not know why this block is so good.

Figure 2 shows normal orchard soil. It consists of a hard, dense matrix with worm and root tunnels through it.

The Constitution of the Aggregate

The aggregates that we see in the photo are properly called macroaggregates. This is because they consist of microaggregates (0.002 to 0.25 mm) that are bonded together. The microaggregates also consist of smaller aggregates, the clay aggregates (smaller than 0.002 mm). The clay aggregates have built up from the ultimate clay particles. Thus the macroaggregates that we see in the photo are made up of a hierarchy of particles.

Table 1 sets out the types of aggregates, how they are formed, their bonding agents and some implications for management in the field. For the orchardist the table tells us that to keep the clay aggregates stable he needs gypsum; to keep the microaggregates stable he needs organic matter, calcium (gypsum and lime) and roots; to keep the macroaggregates stable he needs organic matter, calcium, roots and fungi, minimum tillage, best irrigation and drainage and no traffic. A duplex soil is one that has a surface soil and subsoil that are quite different and sharply separated.

The key factors seem to be, at this stage of our thinking, organic matter and grass roots. We assume growers apply gypsum, lime and fertilisers, provide good irrigation and drainage and avoid over cultivation and traffic compaction (they dedicate traffic into lanes). However our orchard soils have too little organic matter and too little grass.

Organic Matter

My reading, discussions, and pot and field experiments indicate more and more that high levels of organic matter is a paramount need in producing good soil structure. The sources of organic matter in orchard soils can be: added materials such as straw, cover crops, weeds, roots and root exudates, leaves, prunings, slashings.

The form of organic matter can vary from sticks and twigs to finer macro-organic matter, to colloidal (microscopic) material to organic molecules. Soil microbes produce the smaller particles from plant remains. The functions of organic matter are many:

It helps keep soil aggregates and fragments separated, provides a source of energy for soil animals, fungi and bacteria, it is part of the structure within macroaggregates and microaggregates, and it provides organic glues for bonding clay particles and microaggregates.

A model for the build up of stable macroaggregates comes from Dr. Ralph Foster of CSIRO Adelaide, who finds with the electron microscope that roots grow into the soil, then grow root hairs and fine secondaries and support fungi that grow thread-like hyphae.These all exude polysaccharides which act as gums, and when they dry, glue soil particles to the root and hyphae. Eventually these die, but the cellulose fibres from which they are made remain strong and glued into the soil. In this way, gradually a network of ‘cables and girders’ develop in macroaggregates, giving them immense strength and persistence.

Professor Oades, also in Adelaide, has developed a theory in which organic matter

Table 1. Important processes in the formation and stabilization of aggregates in Australian duplex soils

Aggregate	Size range (mm)	Formation and bonding agents	Implications for management
Clay aggregates	< 2	Clay particles condense to form domains and quasi-crystals bonded by electrostatic forces.	Calcium ions and electrolyte needed, both from gypsum.
Microaggregates	2-2.50	Clay aggregates sorbed onto organic fragments stabilized by microbes; bonded by organo-mineral complexes.	Need to build up organic matter and calcium, and rhizosphere. Avoid compressive shear.
Macroaggregates	> 2.50	Roots and fungal hyphae link microaggregates; biological agents mellow and give porosity and resistance to compaction; fungal and bacterial mucilages act as glues and inorganic materials . act as cements	Build up organic matter and calcium. Maximize root and hyphae; growth and minimize tillage. Manage water for slow wetting and good drainage. Dedicate traffic to reduce compaction.

molecules, produced from bacterial and fungal digestion of soil organic matter, combine with calcium (from lime and gypsum) to bond clay particles, clay aggregates and other particles into microaggregates. These are then bound into macroaggregates.

The biology

Roots can be as fine as 0.03 mm in diameter and soil can have as many as 30 cm of root length per cubic cm of soil. Grasses produce the most roots, and rye grass has one of the highest root concentrations. Fungi grow within the roots of certain plants, including rye grass, and their “roots”, called ‘hyphae’, extend out of the root and into the soil. Fungi and their hyphae also grow on decaying organic matter in the soil.

The length of fungal hyphae in soil is very large; beneath a 6 x 5 m fruit tree, in some instances the soil would contain 400,000 km of hyphae. Bacteria and other microscopic organisms also occur in large numbers. A range of small animals are also important in the soil, with the largest being earthworms.

Many of these biological agents are involved in breaking down plant fragments into smaller and smaller pieces and eventually to molecular size. It is from this process that the aggregates obtain the gums, girders and other compounds that make the aggregate stable.

In soil with high organic matter this process is strong. High organic matter also provides a lot of feed for earthworms and other animals that mix the soil constituents. The high organic matter also provides a suit of organic materials that keep the soil open just by their physical presence.

The "rhizosphere" is the soil immediately around the root to a distance of one mm from the root surface, where biological activity is very strong. This is because roots exude polysaccharides (sugar-like substances) that bacteria, fungi, and other microorganisms feed on. Again, rye grass produces large amounts of exudates and with its high root numbers, supports a huge biological activity.

The orchard soil

The normal soil in all orchards contrasts strongly with the ideal virgin-type soil. The original soil, loose at planting, rapidly coalesces to a hard mass. Earthworms and roots can produce pores between 0.5 and 3.0 mm in diameter, and these provide passages for water to soak in through and for soil aeration. But concentrations of tree roots are low because roots do not grow well in larger pores — they cannot contact the soil sufficiently well to take up water and nutrients and they find the matrix between the pores to be too hard. Virtually all zero-cultivated orchards around the world have all of their soil in this condition. When orchardists cultivate this soil it breaks up into fragments, not aggregates. Fragments are dense, angular, hard, non-porous, hold little water and coalesce to a hard mass a couple of months after cultivation.

Mellowing and synthesis

At the microscope level, our aim is to produce aggregates, say 0.25 to 10 mm diameter, that are extremely stable and that are very porous. There may be two approaches to developing this kind of structure, first by changing the fragments we see in a newly cultivated orchard or pasture soil from unstable and dense, to stable and porous (called mellowing). Alternatively by building up stable, porous aggregates out of finer material (synthesis).

Mellowing. The model we can think of here is to set up conditions in the freshly cultivated soil, with high organic matter, roots of grasses, frequent irrigation, drainage, lime and gypsum and others. Then physical and biological activity may mellow the dense fragments.

As the soil dries it shrinks somewhat and when irrigated it swells. Cycles of this cause the gradual development of fracture planes within the fragments. These cycles also cause detachment of fine pieces from the fragment faces and corners. Other planes of weakness form when clay particles within the fragment surround a sand grain. The wetting and drying cycles cause the clay to expand and contract, but the sand grain is rigid, so that tensile cracks form around the sand grain and between grains. Our soils contain 30% sand.

Grass roots, root hairs and fungal hyphae may be able to penetrate fragments when the soil is freshly wet and soft, or may penetrate the fine cracks caused by wetting and drying cycles. Once they have penetrated they are beginning the process of producing fine pores, of adding organic matter and laying in the girders and cables needed for stability. The other agents that could be important in stability and mesoporosity are earthworms and other soil animals. They ingest soil fragments and excrete the soil as slurry.

If the soil contains a lot of organic matter, the slurry when it dries may be far more porous and stable than previously, because organic matter is incorporated. All this is theory at this stage but these ideas have a lot of evidence to support them.

Synthesis. The idea of synthesising stable aggregates comes from several soil scientists, especially in Adelaide. However the most recent model and most appealing is that of Denni Angero, a Canadian soil structure authority who visited recently.

Denni pictures a mass of dense fragments from recent cultivation. At the contact points between fragments he sees the concentrating of roots, root hairs and hyphae. These produce exudates and a huge microbiological activity builds up over months. During each irrigation, very fine mineral soil particles are carried and caught in the network; wetting and drying loosens the edges of the soil fragments. Some roots penetrate and cultivate more fine mineral pieces out into the biological mass; roots die and are replaced. The mineral soil particles and organic structures and pieces thus come together and slowly form a new entity.

Gradually this forms into a super-stable, porous aggregate. He calls these biogenic aggregates. This is more or less theory at this stage. However, my orchard and tomato plots are highly likely to be ideal for this type of activity: they contain high organic matter, grass roots, irrigation and drying, lime, gypsum, nutrients, drainage and no compaction. My microscope will show me when this kind of aggregate develops.

Orchard soil management towards virgin soil

The proposed system outlined in Orchard Soil Management, "A Future System of Soil Management"(in NVFA's Technical Bulletin, Dec 1998) gives the details. This lists thirty inputs needed. Growers currently employ many of these. The important ones though, are the need for very high levels of organic matter and a lot of grass roots in our soils.

Summary

- *The best agricultural soils, including virgin soils, are those supplied with fertilizers, water, and drainage, but also with a loose, soft, porous structure.*
- *To produce virgin-like soils must be the aim of our orchard research.*
- *Virgin soils consist of aggregates that are built up in a hierarchy of several steps, and each step has its own requirements of the orchardists' soil management.*
- *Organic matter is one of the most important inputs.*
- *Grass roots are also vital.*
- *There is a list of other inputs. All of these produce conditions for high biological activity that will develop the super-aggregates that we need.*

[Based on an article in the Northern Victoria Fruitgrowers Association: Technical Bulletin for March 1999].

Horticulture Australia: A3439.

Northern Victoria Fruitgrowers Association: A1406.

THE HEDGEROW WALNUT PLANTING SYSTEM: EXPERIENCES IN SPAIN

N. ALETA & A. NINOT

Institut de Recerca i Tecnologia Agroalimentaries (IRTA)

Centre de Mas Bove, Departament d'Arboricultura Mediterrania. Apartat 415, 43280 Reus, Spain

Introduction

Walnut orchards using grafted trees started to be planted in Spain around 1976, when Californian and French cultivars were introduced. Walnut orchard management was unknown and technologies applied in California and France were assessed.

At present grafted walnut orchards cover around 3500 ha and the Spanish walnut production from regular plantations is about 4000 t. Main cultivars in adult orchards are: Franquette in areas having late spring frosts, and Hartley and Serr in warm areas. Since 1990 the most favoured cultivar is Chandler.

Spanish technology to produce walnuts has now been developed, and orchards are well managed. Pests and diseases are detected and treated in time. *Xanthomonas arboricola pv. juglandis* (Blight) and *Cydia pomonella* (Codling moth) are the main phytosanitary infections. In some places, spray orchard programs should include *Gnomonia leptostyla* (Anthracnose) control.

The extensive semi-intensive plantations are still the most common planting systems in Spain. although some farmers have started planting cultivars like Chico, Vina or Chandler in hedgerows. Experimental hedgerow orchards are being studied by IRTA and some useful results of these trials are reported in this paper. Mechanical pruning is also evaluated .

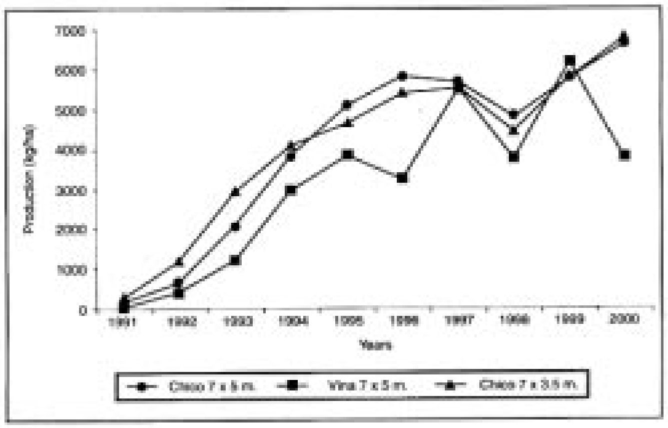


Figure 1. Evolution of nut production in an experimental hedgerow orchard. Planting year 1988.

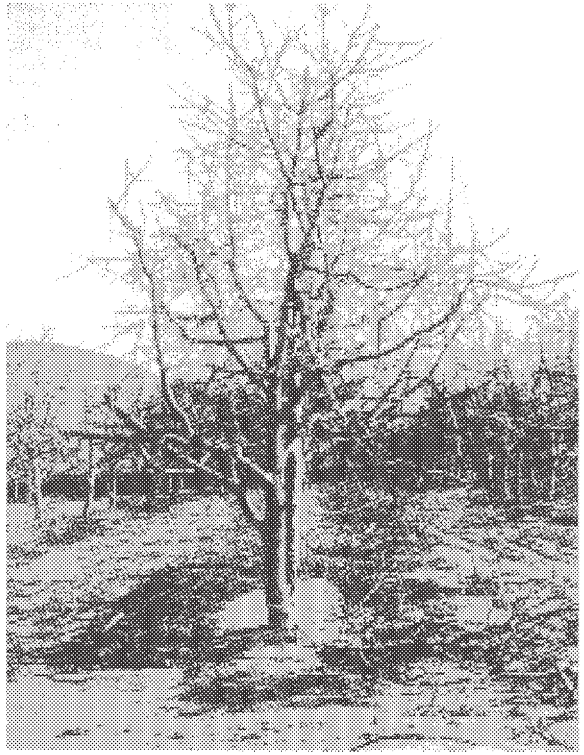
Description of IRTA's experimental walnut hedgerow plot

In 1988 an intensive walnut orchard was planted in the Northeast of Spain, at Bitem near Tortosa, Tarragona as a hedgerow.

The two cultivars chosen, Chico and Vina both had shown a high and precocious productivity in the Mediterranean environment.

Two planting distances were investigated, 7 m x 5 m and 7 m x 3.5 m; trees were trained as central leaders but their primary branches were selected on the row direction. Two trials were established, the first to compare the cited planting distances using Chico and the second to compare cultivar behaviour of Chico and Vina at 7 m x 5 m.

Two pollinators were also included in Serr and Amigo, in parallel rows to those of the main cultivars. Both trials were planned as complete blocks with 3 replications. The number of observations per treatment varied from five at 7 m x 5 m, to eight at 7 m x 3.5 m. Experimental plots are surrounded by guard trees. Both trials occupied 0.9 ha.



Walnut orchard eleven years old. Pyramidal trees at Bitem near Tortosa, Spain.

Orchard walnut management was the usual management as practised in Spain. Orchards were micro-sprinkler irrigated from planting, water requirements and fertiliser applications were calculated considering environment, crop demands and soil characteristics. Tree rows were treated with herbicides in a strip of one metre from the trunk at both sides, when trees were age three years. Blight damage is important in the Mediterranean region and this problem was ever present due to the susceptibility of both main cultivars used. Strict spray scheduling is followed for diseases and pests.

Trees were trained from the fifth to the seventh year from planting. Later, manual pruning was carried out until 1996, with main axis and primary branches cut back each year to get vigorous growth. The green wall should reach 7 m as this row distance is suitable for an orchard located at 40° northern latitude. Since 1997, mechanical pruning has been applied annually.

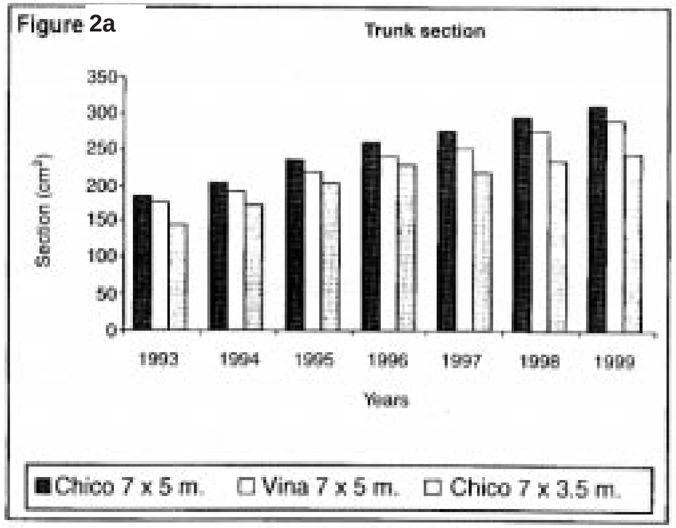
Due to little experience in that technique, two treatments were assessed. In the first treatment pruning is applied annually, each year on one side of the row. In the second treatment pruning is applied biennially, first year one side is pruned, the following year nothing is cut and the third year the other side is pruned. At the end of the pruning cycle there is a year of resting before starting to prune again. In both treatments the green wall is cut back to 1.8 m from the trunk following a pyramid of 60° and the base starts at 1.5 m from the soil level. Central leaders are cut each year to stimulate tree growth.

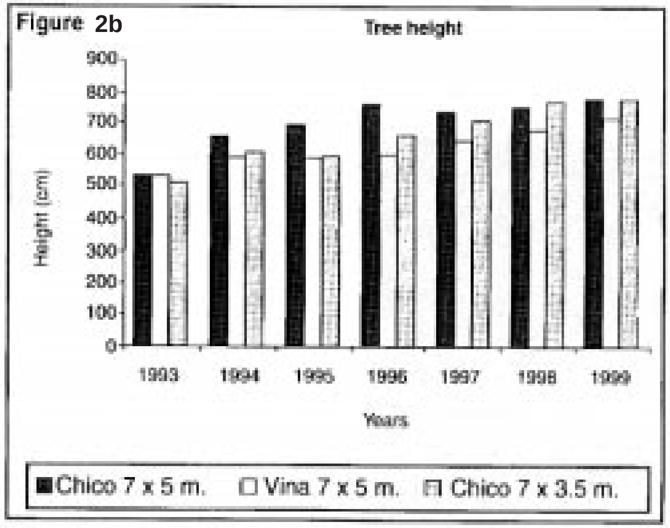
Some relevant productive and vegetative results

Vegetative and productive behaviour has been assessed each year. The pattern of production is shown in Figure 1. On the third year after planting, 1991, the first nuts were harvested and the cultivar Chico reached up to 0.3 t/ha at 7 m x 3.5 m planting distance. Obviously more trees per hectare leads to more production during the juvenile phase of the orchard.

Chico planted at 7 m x 5 m was significantly more productive than Chico at 7 m x 3.5 m after 1995. In Figure 2a, trunk section growth could give a response to those productive results. Vegetative competition seems to have started in 1993, with trunk section growth significantly less at low planting distance.

Differences in growth affected the nut production of the following harvest, as it was foreseen. The 1994 harvest was similar for both planting distances, but the following year and later trees of the largest planting distances were always performing best. Trunk section in Vina was also



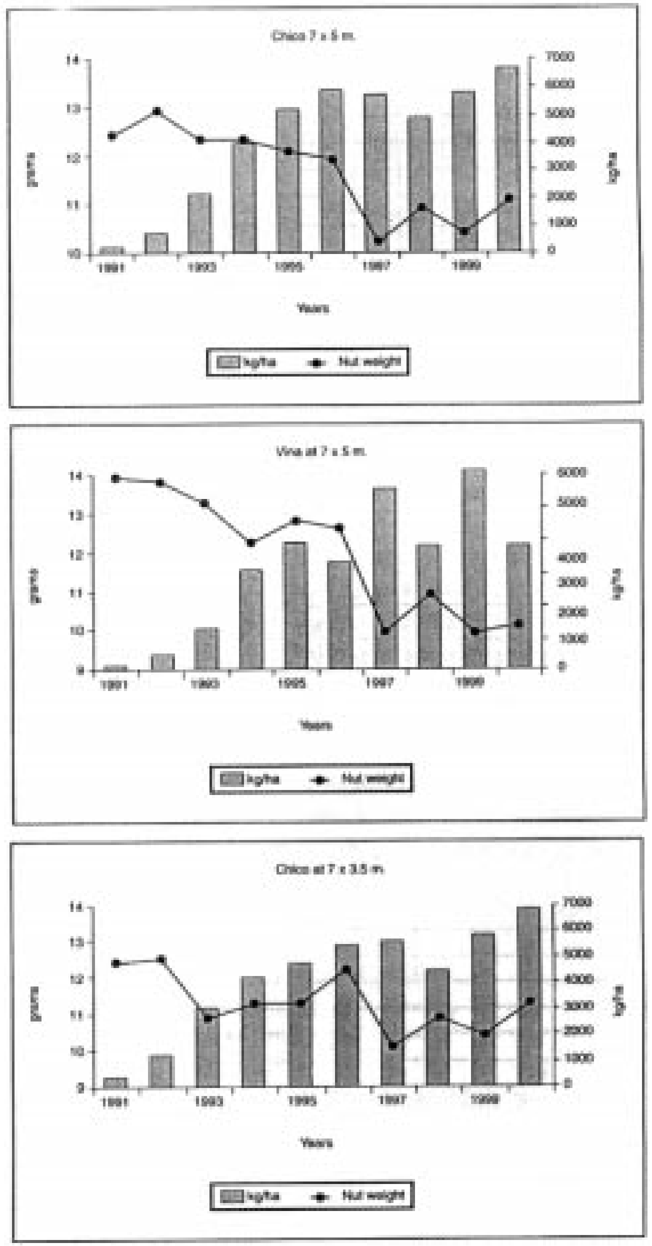


Figures 2a and 2b. Evolution of vegetative growth, trunk section and tree height in a hedgerow experimental orchard. Planting year 1988.

significantly less than in Chico after 1995. If tree height is considered, differences between planting distances are present only during the first years, later indiscriminate pruning makes trees more vigorous (Figure 2b). Vina is more difficult to manage in a hedgerow system than Chico.

In the juvenile phase, nut size, measured as the mean weight per nut, starts to be higher than expected in all cultivars. When orchard production increases it tends to go down. This general rule should be considered particularly in intensive orchards where nut production increases very fast.

In Figures 3 we show that the cultivar Chico spectacularly reduced its nut size in 1997. This year corresponds to the second consecutive year in which the production gets up to 5 t/ha. Mechanical pruning applied in February 1998 stabilised production and even increased it, while nut weight proved to be difficult to increase. However it seems that equilibrium around 11 g nut weight could be reached. Nut size of Vina is described as bigger than Chico, but because of its high



Figures 3a, b, and c, Nut weight in relation to production under two planting distances and for two cultivars in an experimental hedgerow orchard.

susceptibility to stress, production does not allow initial size to be achieved even by applying indiscriminate pruning.

High productivity used to be the result of accurate orchard management. In intensive production systems, pest and disease controls are more difficult than in extensive orchards because it is difficult to get good aeration and spray application through the green wall. Productive data reported from experimental plots correspond to estimate production, but an important percentage of losses was registered each year, mainly due to blight disease. Both Chico and Vina are highly susceptible to blight and losses in the experimental plots ranged each year from 20 to 30% of the crop.

Pruning is one of the most important orchard management costs. Farmers train young trees but often they do not prune adult orchards regularly. Under those conditions orchards get old prematurely and production decreases in volume and quality. The use of mechanical pruning should be a solution but in hedgerow walnut orchards it is a necessity. As it could be observed, the use of indiscriminate pruning has maintained a high level of production in the experimental plots studied. Results of pruning management trials are still preliminary but comment should be made of a striking result. The pruned side of a hedgerow produces not only less nuts, which is logical, but also their size is significantly less than the nuts from unpruned sides. This result seems to suggest that too much vegetation is eliminated, and in this case perhaps pruning every two years will produce better results. In semi-intensive orchards biennial pruning was already the best advice.

Final comment

Twelve years of walnut orchard trials in hedgerow control show that it is easy to get high production quickly if appropriate cultivars are used in this intensive planting system. Chico seems to be a very well adapted cultivar as Californian orchards already demonstrated (Ramos et al., 1997 and 2000), showing better results at 7 m x 5 m than at 7 m x 3.5 m. Vina showed difficulties in maintaining growth and nut size under those trial conditions. This latter cultivar has a remarkable alternacy in producing, however both cultivars reached very high production. The losses associated with blight damage give cause for being selective when making main cultivar choices.

Other cultivars such as Chandler, Howard, Tulare, Lara or Fernot are cited as suitable for hedgerow orchard systems. Two essential features should be required in a cultivar to be hedged: high lateral bearing and low to medium vigour. It will also be advisable to use cultivars easy to train (Germain et al. 1999; Ramos et al. 2000).

[Based on an article in FAO - Nucis-Newsletter, Number 9, December 2000]

IRTA: A2026.

Nucis-Newsletter: A3287.

THE JUJUBE: *ZIZIPHUS JUJUBA*

MARTIN CRAWFORD §
Agroforestry Research Trust
46 Hunters Moon, Darlington, Totnes, Devon TQ9 6JT, UK
<mail@agroforestry.co.uk>

Introduction

Cultivars of *Ziziphus jujuba* (Syns. *Z. sativa. Z. vulgaris*) — jujube, Chinese jujube, red date or Chinese date — have long been grown for their excellent dessert fruits. Native to temperate Asia, where there are many cultivars grown for fruit, jujube has become naturalised in many other warm temperate and subtropical regions; jujube plants were brought from Syria to the Mediterranean in ancient Roman times. In China it is considered one of the five principal fruits.

Description

The jujube is a deciduous shrub or tree growing to 9 m high and 7 m (wide with drooping branches, flexuous twigs, and pairs of short curved and occasionally long spines. The jujube is unusual in that it sheds many of the short lateral-bearing twigs — ie it has deciduous branches as well as leaves. This branchlet loss gives the tree a distinctive zig-zag appearance in winter. Trees often send up suckers many feet from the mother plant.

As the growing season commences, each node of a woody branch produces 1-10 branchlets, most of which are deciduous and fall in the autumn. Leaves are 2.5-6 cm long, elliptic, leathery, shiny, on short stalks.

Flowers are small and yellow, about 5 mm across, in axillary clusters of 2-3 on the current season's growth from the small lateral branchlets. They appear in late spring or summer, depending on the climate; flowering can continue over an extended period, although each flower is receptive to pollen for a day only. Pollination is via insects, including bees; although trees are usually self-fertile, fruits are bigger and more numerous with cross pollination.

Fruits are between a cherry and a plum in size, 1.5-4 cm long, roundish-egg shaped like small plums (sometimes round or pear-shaped). The amount of flesh is very variable between selections. The skin is bright green and shiny when the fruit is mature — at this stage the flesh is crisp, sweet, with an apple flavour; if left on the tree, the skin begins to brown in a few spots, the brown areas coalesce to completely cover the surface, then the fruit begins to dry and wrinkle; by the time it is fully ripe the jujube is a rich red-bronze and most resembles a prune or dry date — hence the name Chinese date. The texture now is chewy and resembling a date, and the taste has improved.

§ Member, WANATCA

The fruits contain a single, hard-shelled stone which encloses one or two seeds.

Under natural conditions, *Z.jujuba* forms a deep and substantial taproot, making it drought tolerant. The tree is winter hardy to zone 6, -20 °C, but shoots may get cut back by less severe frosts than this if not properly ripened. It has a short chilling requirement and tolerates extreme heat, 40 °C or more.

Uses

The fruits have a pleasant acid taste when fresh, but are usually allowed to dry on the tree, when they are chewy and more palatable. The rough and sharp-pointed seed shell is not very suitable for young children. They are used as a substitute for dates and used in savoury dishes — rice, fish, soup — and in cakes. In Asia they are sometimes ground into flour and used for bread; they can be added to bread mixes. The fresh fruit pulp contains about 9% sugars, 1.7% pectin, 2.5% protein and 200-350 mg vitamin C per 100 g of pulp. Fresh green fruits are sometimes used to make jams.

The dried fruits contain 20-35% sugars (just under half that being sucrose, the rest fructose and glucose) and are rich in Vitamin C. Oriental food shops often sell Chinese dates which have been boiled with sugar and honey — the most popular Chinese way of eating them. In Korea, jujube flour is used in the preparation of 'kochujang', a fermented hot pepper-soyabean paste that resembles miso. An edible oil can be obtained from the seed — though presumably yields are low as the kernel is small.

The fruits are also medicinal (being anodyne, anticancer, pectoral, refrigerant, sedative, stomachic, styptic and tonic), and widely used in Chinese herbal medicine for arthritis and insomnia. They are often used in mixtures with other species parts and such mixtures have been shown useful in treating hepatitis B. They are used in the Himalayas as an antidote to aconite poisoning and for nausea and vomiting; for abdominal pain during pregnancy; and externally in poultices for wounds.

The fruits were often used (possible in the boiled-with-honey form) in Britain to alleviate coughs and sore throats, and were formerly imported into Britain in large quantities from Southern France for this purpose.

The seeds are used in Chinese medicine (being hypnotic, narcotic, sedative, stomachic and tonic) for insomnia, amnesia, vertigo; the root is used for dyspepsia, as a powder for wounds and as a febrifuge. The plant is widely used in China as a treatment for burns.

The leaves are also medicinal, being astringent, febrifuge and laxative and prescribed in the Himalayas for scabies and throat troubles. A broth is made from the leaves in Tadjikistan and used for treating liver, kidney and stomach problems, and to improve vital functions. In China they are used for fevers and are said to promote hair growth.

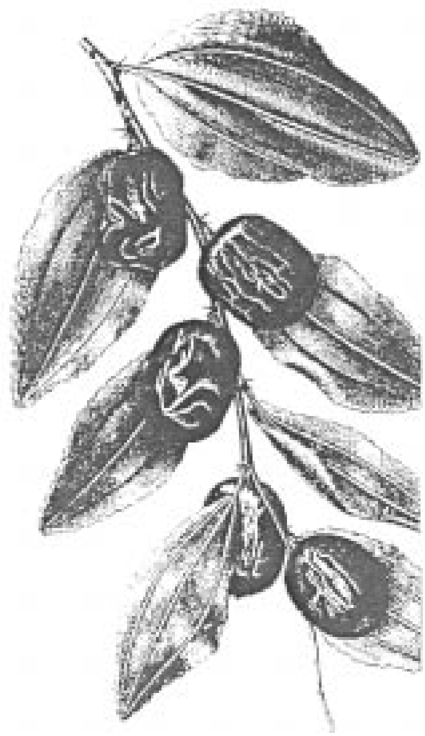
The wood of the tree is very hard and durable, and used to make agricultural implements and for turnery. It makes good fuel and charcoal.

The leaves are used as a fodder for sheep and goats in the Himalayas. They have also been used for silkworm fodder in China.

In China, jujube is widely used in shelterbelts, with over 200,000 ha planted, with optimum spacing of rows 3.7 m wide (presumably 2 lines of trees), with alleys between rows of some 14 m width, where cereals like wheat are grown.

Jujube is also used to stabilise mountainous slopes from erosion, and is regarded in Central Asia as one of the best crops for this.

The leaves have an antifungal effect against several fungal diseases including leaf spot of cotton & onion (*Alternaria tenuis*) and leaf blights (*Helminthosporium* sp.). The jujube is also an attractive ornamental tree.



Cultivation

Jujubes can be grown for fruit production in warm temperate or subtropical climates; hot dry weather is required for good fruiting. In areas where there are prolonged or severe frosts, the plants need the protection of a cool or intermediate glasshouse if fruiting is desired. In Britain, lack of summer heat can often prevent good fruiting and growth.

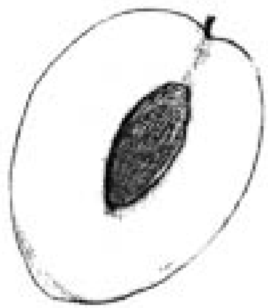
Grow in any well-drained soil, including alkaline and saline soils, in sun. Jujubes like low humidity during the growth season and a dry soil in winter. Pot-grown trees may need regular root pruning to prevent the formation of a dominant long tap root. Jujube orchards should be planted at 7-8 m by 4-5 m — the larger spacing on more fertile soils and for more vigorous trees. Growth in Britain is about 2 m in 10 years.

Pruning should be carried out during dormancy in winter. Fruit is borne on the current season's growth, hence there is no danger of pruning off fruiting wood; pruning should concentrate on removing dead or dying wood, and keeping the tree open and well ventilated. Initially it may be wise to select a framework of 3-4 branches in a pyramid form.

In China, girdling is commonly used to increase yields by up to 200%. A circular strip of bark is either removed or reversed on the main trunk of the tree. This procedure also causes the tree to set fruit earlier and ripen at the same time — it shortens the harvest time. The harvest time itself can be manipulated by girdling at different times. After a tree has been girdled every year for many years, it can be cut off totally and allowed to regrow.

Fruiting on grafted plants starts after 2-4 years; seedlings may take 3-7 years. The first few crops do not give a true indication of eventual fruit size. Although trees are usually self-fertile, fruits are bigger and more numerous with cross pollination.

Harvesting can begin as soon as the green fruits develop a few brown spots on the skin — they will then fully ripen off the tree; if you have dry conditions, then leave them on the tree to ripen and harvest them as they fall to the ground. The fruits ripen gradually (over a month or more) and not all at once, and should be picked or shaken every few days over this period. In China, harvest normally takes place early in the morning before the dew dries — this is supposed to improve the flavour and texture of harvested fruits. Yields vary tremendously but can average 45 kg per tree or more for mature trees.



In humid climates, fruits should be picked when starting to turn brownish-red and dried either in a solar dryer and/or in an oven at 45 °C, stirring frequently. If not picked, rain and humid weather can cause the skin to crack, and then fungi can develop in the cracks.

Fresh ripe fruits will keep for 1-2 months at 10°C or for 1-4 weeks at room temperature; dried ripe fruits will keep for a year at cool temperatures and 50% relative humidity. They should be kept in unsealed containers. There are few pests or diseases.

Cultivars

Most of these originated in China and arrived in the West via the USA in the early 20th Century. China currently has over 400 superior cultivars, although only a handful are obtainable in the West. Seedling trees come relatively true to their parent, although they take a few more years to bear fruit.

Admiral Wilkes: Fruit elongated, 50 mm long, very late to ripen.

Ant Admire: Fruits medium sized, narrow, elongated, very sweet; mid season ripening. From China.

Chico: Fruits small, round, often seedless (seed is round when present), good to eat green when crisp and acid; tree thorny, needs hot location. A Californian selection.

Davis: Fruits of excellent flavour; productive tree. From the USA.

GA 866: Fruits elongated, 50 mm long, very sweet, mid-season ripening. Tree has few thorns. From California.

Geant Sloboda: A selection from the former USSR.

Honey Jar: Fruits very small (under 25 mm across), round, extremely sweet both fresh and dried. From China.

Jin: Fruits very uniform, elongated, 50 mm or more in length, very small seeds. Dried fruits are very chewy and date-like. Ripens early; hangs on the tree well after drying.

Lang: Fruits large (up to 50 x 40 mm), pear shaped, with a thin shiny skin and sweet, melting plentiful flesh with a hint of caramel flavour; tree large, upright, early bearing, generally has only a few thorns. Good fresh, excellent dried. Mid-season ripening. Origin: China.

Li: Fruits very large (to 50 mm in diameter), round, excellent flavour, good to eat green, flesh sweet and crisp, and with a small stone, early season ripening; will ripen if picked at the yellow-green stage. Tree large, spreading, suckering. Origin: China.

Redlands 4: Fruits large, round, like Li but larger; excellent sweet flavour and crisp texture; mid season ripening. From California.

Sherwood: Fruits very large (40-50 mm long or more), flesh of excellent quality, dense; very late ripening. Will keep for 6 weeks in refrigeration. Tree with small or no thorns, very productive. From Louisiana.

Shui Men: Fruit medium sized, elongated, sweet-acid flavour, good fresh or dried; ripens mid season. Tree a good bearer, with small thorns. Origin: China.

Silverhill (Silverhill Round, Tigers Tooth)**:** Fruits large (25 mm across by 40-50 mm long), elongated (plum shaped), with sweet solid flesh, good for drying, mid season ripening; tree large with few suckers or thorns, a prolific bearer. From the USA (Georgia).

So: Fruit round, of excellent flavour. Tree branches grow in a zig-zag manner.

Sugar Cane: Fruits small-medium sized, oval, 25 mm long, very sweet and crunchy, very dense, small seeds. Tree thorny. From California.

Sweet Meaty: Fruits round, meaty; very late ripening. Tree with large thorns.

Tajanczao: A selection from the former USSR.

Texas Tart: A high acid jujube. Origin: Texas.

Yu: Fruits large, elongated, tapering at the bottom; flesh sweet, firm, good keeping qualities. Tree tall with few side branches and large leaves, and few thorns. Origin: China.

Other cultivars grown in the former USSR (particularly Tadjikistan, Uzbekistan, Azerbaijan) include **Kitaiskij N** selections, **Azerbaijanskij N22, Apsheronskij, Mardakyanskij N1, Tadjikskij N24** and **Shirvanskij**.

Propagation

Seed propagation is fairly easy. Jujube seeds have a hard, rough, pointed outer shell which has a distinct suture line aligned from end to end. This shell needs to be removed to facilitate reliable germination; the best way is to carefully align the suture in the blades of a pair of secateurs and cut firmly — the seed usually comes out unscathed from this operation!

The naked seeds are then not dormant and should be sown immediately in the warmth; germination takes place over the next 2-5 weeks. A few weeks of cold stratification sometimes aids First year growth can reach 20 cm. There are about 2400 seeds per kg.

Cutting propagation is difficult but possible. Take greenwood cuttings in summer about 15 cm long, just as the base is starting to harden, and use mist and bottom heat. The success rate may be as low as 10%, but it may be worth it to get trees on their own roots, whose suckers will be identical to the mother tree.

Cultivars of *Z. jujuba* are usually propagated by grafting onto jujube seedlings or seedlings of the related *Ziziphus rotundifolia* — the latter limits top growth and is better suited to pot culture, but is not very hardy. A whip and tongue graft is used with the previous season's wood at least 7 mm thick. Jujubes can sometimes be propagated by root cuttings — success depends on the cultivar.

Suppliers UK

Agroforestry Research Trust, 46 Hunters Moon, Dartington, Totnes, Devon, TQ9 6JT. Seed & sometimes seedlings.

Burncoose & South Down Nurseries, Gwennap, Redruth, Cornwall, TR16 6BJ.Tel: 01209 861112. Supplies 'Lang'.

Hollington Nurseries, Woolton Hill, Newbury, Berks, RG20 9XT. Tel: 01635 253908. Supplies 'Lang' and 'Li'.

Reads Nursery, Hales Hall, Loddon, Norfolk, NR14 6QW. Tel: 01508 548395. Supplies 'Lang' and 'Li'.

Suppliers USA

Edible Landscaping, PO Box 77, Afton, VA 22920. Tel: 804-361-9134.

Roger & Shirley Meyer, 16531 Mt. Shelley Circle, Fountain Valley, CA 92708. Tel: 714-839-0796. Supply many rare cultivars.

References

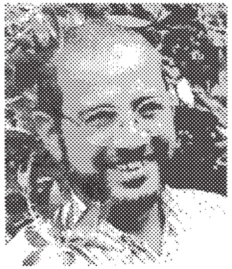
Bean, W J: *Trees and Shrubs Hardy in the British Isles*. John Murray, 1974.
Burmistrov, L: *Jujube in Russia*. Fruit Gardener, Vol 26, No 4 (Dec 1994), p4.
Ciminata, P: *Jujube talk*. Quandong, Vol 22 No 1, P 14-16.
Duke, J & Ayensu, E: *Medicinal Plants of China*. Reference Publications, 1985.
Facciola, S: *Cornucopia II*. Kampong Publications, 1998.
Glowinski, L: *The Complete Book of Fruit Growing in Australia*. Lothian Books, 1997.
Grange, M & Ahmed, S: *Handbook of Plants with Pest-Control Properties*. Wiley, 1988.
Huxley, A: *The New RHS Dictionary of Gardening*. Macmillan Reference, 1999.
Johns, L & Stevenson, V: *The Complete Book of Fruit*. Angus & Robertson, 1979.
Krussmann, G: *Manual of Cultivated Broad-Leaved Trees and Shrubs*. Batsford, 1985.
Meyer, R: *Jujube Variety List*. Quandong, Vol 19 No 2, p 21-22, 1993.
Parmar, C & Kaushal, M: *Wild Fruits of the Sub-Himalayan Region.* Kalyani Publishers, 1982.
Reich, L: *Uncommon Fruits Worthy of Attention*. Addison-Wesley, 1 991.
Wertz, H: *Jujube notes — Propagation, Drying & Hardiness*. Pomona, Vol xxiv No 3, p 61-62.
Whealy, K & Demuth S: *Fruit, Berry and Nut Inventory*. Seed Saver Publications, 1993.

[Based on an article published in Agroforestry News, Vol. 9 No 1, October 2000].

Agroforestry News: A2768.

Agroforestry Research Trust: A2769.

DESERT CLIMATES, POOR WATER AND OLIVES



MOHAMED EL-KHOLY
Sayeda Zeinab & Pharaoh's Olive Groves
10 Mohamed Tawfik Diab Street,
Nasr City - 6 District, Cairo 11371, Egypt.
<adkholy@hotmail.com>

This informative article was written as an Egyptian field model for Mediterranean developing countries as part of an international course on Land and Water Use for Sustainable Olive Growing. The course, organised by the International Olive Oil Council, was held in Naples, Italy, in September 2001.

Although there are considerable differences between Egypt and Australia, there are many regions in our country that also suffer from low rainfall, salty water, poor soil and a harsh climate. These detailed findings will prove very useful for the olive industry in Australia's more arid regions and many of the issues discussed will benefit growers with fully-irrigated groves in any location.

Introduction

Olive trees can play a vital role in sustainable development and soil conservation in low rainfal1 and even full desert regions through the use of poor natural resources such as infertile sandy soil and saline water. Such development has been achieved through field-applied techniques and practices, which will be discussed.

Poor quality water exists almost everywhere in the world where the increasing lack of fresh water is about to threaten large populations in different locations. To appreciate the need to use poor quality water whenever possible in agriculture, it is imperative that the Egyptian situation with its water and land resources be discussed.

Growing fully irrigated olive trees (totalling 14,400) through the application of integrated management under the above-mentioned unfavourable conditions, the author has been able to prove through personal experience over the last 13 years that olives can be an excellent cash crop. Where other fruit trees die, the olive tree can thrive.

Egyptian water and land resources

(This section has been summarised from the original paper)

The land is mostly desert and due to water scarcity only 4% of the total area is used for agriculture. Rainfall does not exceed 50 mm per year north of Cairo, but in some years it can reach 80 to 200 mm on the northern coast facing the Mediterranean. Under such conditions rain cannot be relied on as a water source for sustainable development.

The main factors that threaten the Egyptian soils are wind erosion of the open uncovered desert land, salinization of old rural lands, shifting of existing sand dunes, urban expansion on the cultivated lands and finally, sea water level rise which threatens the northern low coast of the delta.

The water resources of the country are limited to 66.1 billion m^3 of which 55.5 billion m^3 is from the Nile and the rest from recycled drainage, treated sanitary, and underground aquifers. Consumption figures of 1998 statistics were 65.1 billion m^3, indicating a serious growing shortage in the coming years due to population increase — therefore exploiting new underground resources is becoming a necessity and, in particular, those with poor quality water.

The above critical situation calls in general for a more efficient sustainable management strategy of water and land resources. This strategy must place emphasis on the underground aquifers especially non-exploited ones or those with poor water quality to be utilised in increasing the cultivated area.

Recent years are characterised by extreme changes in weather conditions specifically during late winter and spring. The climate in 1999 was very similar to 1998 but heat waves were less intense. In 2000 the chilling temperatures were very satisfactory. Nevertheless the low winter temperatures were dominant till mid spring, slowing down the maturity of the sexual organs of the flowers. This period was followed by sudden heat waves during fruit set, burning set drupes.

The problem of climate change is still prevailing this year (2001), however with less effect than the last three years, and the average yield is expected to be roughly 65 kg/tree. Other than the Cipreccino, the cultivars planted in 1998 were all Egyptian — namely Hamed, El-Massery, Toffahi, Aggezi Shami and Sinnara — and yielded an average of 6.2 kg/tree in the crop year 2000.

Why Grow Olives Under the Above Conditions?
The Egyptian Land and Water Resources Situation

The challenges facing land reclamation on the above location are many. Starting with the need to build up soil fertility, which in addition to being poor, has a high sodium adsorption rate (SAR) of 11 to 15 along its cultivable profile. Using poor quality water forces the selection of a suitable crop and the implementation of management practices that should aim at preventive measures and integrated problem solving to aid in controlling the harmful impacts of salt accumulation on both the plants and the soil. Such practices have resulted in relatively high crop yields. These yields have not only been achieved through proper leaching of salts but also through improving the soil with amendments, all within an Integrated Grove Management System (IGMS).

Olives are characterised as being drought resistant with low water requirements, moderately salt tolerant and can be commercially grown on poor but well-drained soils. The local climatic conditions satisfy chilling requirements and most importantly are distinguished by temperature

The Egyptian Olive "Field Model" Under Desert Conditions, Infertile Soil and Poor Quality Water

Location, Environmental and Soil Conditions and Grove Data:

<table>
<tr><th colspan="15">Table 1 - Location & Environment</th></tr>
<tr><td colspan="3">Geographical</td><td colspan="12">Latitude 30°09'21"   Longitude: 32°09'21"   Altitude: 68.30 masl</td></tr>
<tr><td rowspan="8">Region Climatic Conditions</td><td colspan="2">Characteristic</td><td colspan="12">Desert of hot rainless summers and mild winters with scarce rain.</td></tr>
<tr><td colspan="2">Rainfall</td><td colspan="12"><30mm annually. Precipitation rate doubtfully has any recharge on the present groundwater aquifier underlaying the grove.</td></tr>
<tr><td colspan="2">Wind</td><td colspan="12">Generally mild. Seasonal sand storms during spring with velocity that can reach up to 100km/hr (known locally as Khamaseen) causing soil erosion. Normally associated with abrupt heat waves (33°C to 42°C).</td></tr>
<tr><td colspan="2">Light</td><td colspan="12">High intensity due to generally cloudless sky permitting full sunlight.</td></tr>
<tr><td colspan="2">Humidity</td><td colspan="12">Ranges from a mean minimum of 48% in April up to mean maximum of 68% in November. Temporarily can reach over 90%.</td></tr>
<tr><td>Mean</td><td>month</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr>
<tr><td>Temp</td><td>min</td><td>7½</td><td>8½</td><td>10½</td><td>13½</td><td>16</td><td>18</td><td>22</td><td>22½</td><td>20</td><td>17½</td><td>13½</td><td>10</td></tr>
<tr><td>°C</td><td>max</td><td>20</td><td>21</td><td>24</td><td>26</td><td>32</td><td>35</td><td>36</td><td>36½</td><td>33</td><td>31</td><td>26</td><td>22</td></tr>
<tr><td rowspan="4">The Water</td><td colspan="2">Aquifer</td><td colspan="12">Two types of aquifiers characterize the underground water resources in this region. The Grove is located on the southern boundaries of the main fluvial aquifer having its minimum thickness of 50 metres and highest salinity of >5000 ppm which increases vertically downwards towards the underlying Miocene marine sediments. Therefore the pumped water is characterized by being rich in Calcium, Sulfate, Sodium and Chloride as typical salts of old marine origin. At its Northern boundaries the aquifier possesses a greater thickness of 350 metres and the water is characterized by lower salinity of <2000 ppm.</td></tr>
<tr><td colspan="2" rowspan="2">Salinity ppm</td><td>1988</td><td colspan="2">5200 summer
4650 winter*</td><td colspan="9">* Lower salinity due to reduced pumping.</td></tr>
<tr><td>2001</td><td colspan="2">7488 summer
6100 winter*</td><td colspan="9"></td></tr>
<tr><td colspan="2">Well</td><td colspan="12">12", 141m deep equipped with electrical submersible 4"/48m³/hr pump. Static water level - 64.9m in 1988. Level gradually dropped to - 66.1m in the first 4 years then gradually regained same static level of - 64.9m.</td></tr>
</table>

fluctuations between day and night and between seasons. This is a major criterion for growing olives. The negative impact on flowering by seasonal, irregular, sand storms and heat waves during spring can be minimised through adequate water management, nutrition and windbreaks.

Growing olive trees, which are strikingly characterised by their longevity makes them very suitable under the prevailing conditions as a sustainable crop for the coming generations. It allows prolonged depreciation of assets and the seed capital investment is only once in a lifetime.

Although olive oil prices are still relatively higher than other vegetable and seed oils, with increased consumer awareness of olive oil health benefits, growing olives can contribute in narrowing the gap between national oil production and consumption.

In view of the General Agreement on Tariffs and Trade (GATT), capitalising on the environment by growing a suitable fruit crop, adaptable to desert conditions (that is, dates, olives and figs), will prove in the long term to be more profitable than growing moderate climate deciduous crops.

In a highly populated country with high rates of unemployment, olives can offer employment opportunities for 3 to 4 months during harvesting and at least 20% of those staff during the remainder of the year. Hand harvesting will add value to the fruits' quality.

Strategies to grow olives successfully using poor-quality irrigation water

Figures 1 and 2 indicate the strategies which must be adopted to ensure long-term successful olive growing when using poor-quality water. Applying Integrated Grove Management Systems (IGMS) will result in good returns and reduced negative impacts on both the trees and the soil.

Although olive trees are well known for being moderately salt tolerant, some varieties are slightly tolerant while others are highly tolerant, therefore the crux of the guide triangle shown on Fig. 1 is variety selection. This should receive utmost care so that the variety is adaptable to the level of water salinity in use. Points indicated on Fig. 2 are not in order of preference and are discussed later.

Managing Land Preparation Practices Focusing on Soil Conservation Under Saline Water Use

The ultimate objective is to improve soil fertility as well as reduce the harmful impacts of saline water on the soil and trees.

At tree locations, pits 700 to 800 mm diameter x 900 to 1100 mm depth are excavated (Fig. 3, step 1) and backfilled with a balanced mixture of the excavated soil, composted organic manure, gypsum and some macro elements, namely phosphate, potassium, magnesium and sulphur (Fig. 3, step 3). The incorporation of compost into the deep profiles of this soil will provide a buffering zone against salt accumulation from the irrigation water. It will also act as a storehouse for added nutrients.

Application of the compost is also mandatory for this type of soil to enhance its poor microbiological activity, improve its low exchange capacity, its water holding capacity, and stabilise its structure. Gypsum is used not only for supplying the olive trees' high needs of calcium but also to lower the soil pH in association with elemental sulphur and to aid in

Table 2 - Soil & Grove Data

Topography	Maximum of 0.6% undulation within the grove
The Soil	Approximately 85% of the Grove area is permeable sandy loam soil with deep drained profile. Varying with the ground level elevation, about 10% localized section spots have 2 clayey hard pans within the profile; one between - 15 and - 70cm and the other between - 165 and - 300cm. On the remaining 5% the hardpan extends from - 80 to 135cm.

The Soil – Virgin Non-Cultivated Soil Analyses (1:1 extract)

Depth cm	0 - 20	20 - 40	40 - 60	60 - 80	80 - 100	100 - 120
EC dS m^{-1}	2.1	2.5	2.6	3.3	4.2	4.9
pH	8.0	8.2	8.2	8.1	8.0	8.0
$CaCO_3$%	2.0	2.7	2.5	3.1	4.1	4.9
$CaSO_4$mg/gm	0.8	2.0	1.5	1.2	1.6	1.6
Na^+	18.0	17.5	20.0	25.0	29.6	37.0
Ca^{++}	4.1	6.0	5.1	7.4	8.7	9.1
Mg^{++}	1.3	2.1	1.1	1.1	2.3	2.5
K^+ppm	182.0	148.0	132.0	90.0	80.0	70.0
P ppm	12.0	10.0	11.0	5.0	2.0	---
Cl	14.0	17.0	16.8	22.1	25.2	32.0
SO_4	6.8	7.0	8.2	10.7	14.8	14.8

The Grove

No. of Trees		A total of 14,400 olive trees.
Planting Densities		Different intensive densities of 400 trees/ha (5m x 5m), 278 trees/ha (6m x 6m) and high density of 606 trees/ha (6m x 2.75m)
Cultivars	Majority	Picual, Manzanillo, Cipreccino, Aggezi with its subcultivars (Shami, Akks, El-Massery & Sinnara), Toffahi and Hamed.
	Minority	Koroneike, Dolcy, coratina, Frantoio, Nabali, Kalamata & others.
Planting History	1988	2000 olive trees + 6000 citrus trees.
	1989-90	6000 olive trees replacing 1988 citrus not growing satisfactorily due to water salinity and bad choice of root stock (sour orange) for the sandy loam soil and the desert environment.
	1998	6400 olive trees of which 2400 Cipreccino cultivar used as windbreaks. High yields obtained in the preceding years encouraged plantation of high intensive density of 6m x 2.75m.

Average Yield Records Kg/tree

Crop Year	Non Local Cultivars		Local Cultivars					
	Picual	Manz	Massery	Akks	Shami	Sinnara	Hamed	Toffahi
1988	Plant	Plant						
1989			Plant	Plant				
1990	2.2	1.6			Plant	Plant	Plant	Plant
1991	18.0	22.6	4.3					
1992	40.4	30.2	22.6	12.2	5.2	4.4	5.4	4.2
1993	64.0	46.0	40.3	43.0	30.8	29.8	24.5	25.9
1994	56.4	68.4	56.9	62.6	42.6	55.3	49.0	46.3
1995	88.0	81.2	76.4	91.1	69.0	63.7	73.8	61.5
1996	106.3	90.1	87.0	73.7	73.5	81.4	90.0	83.1
1997	131.1	115.9	93.5	98.2	101.1	99.6	111.6	92.5
1998*	*Very low crop due to prolonged hot sandy storm winds that hit all cultivars during flowering & fruit set (22.8 kg/tree average).							
1999*	36.6	42.0	41.2	64.0	53.8	66.2	75.7	60.3
2000*	26.7	21.5	29.2	39.0	35.6	41.0	25.2	30.5

leaching sodium salts to overcome the expected build up of impermeable salt sealants, created from using high TDS (Total Dissolved Solids) water, which may waterlog the soil [$CaS0_4$ (gypsum) + $2NaCO_3 > Ca(C0_3)_2 + Na_2SO_4$ which can be leached out].

In spots of hardpans, extra quantities of compost and gypsum are used to serve as a binding agent to the fine clay particles making larger and water-stable aggregates thereby improving drainage and aeration at localised spots.

Fresh manure is never used, as decomposition in the soil is decelerated and the acid gases released during anaerobic processes slow down the root system development. Composted manure also contains less salt than fresh manure.

If hardpans are exposed while excavating the pits, a 125 mm hole is augered starting from the bottom of the pit to a depth of 5.5 m from the soil surface. The hole is then filled with 5 to 10 mm fine gravel to function as a localised drain to prevent increased salts accumulation.

After backfilling, gypsum is spread on the soil surface in two-metre strips along the rows and is incorporated through three deep rips along and across the rows (step 4). The process is also intended to break up the shallow clayey hardpan, which would affect the roots' penetration and soil water infiltration.

Benefits of deep ripping

It has been noted that deep ripping has created a deeper root zone, improved soil holding capacity and drainage, achieved reasonable mixing of all added soil amendments and

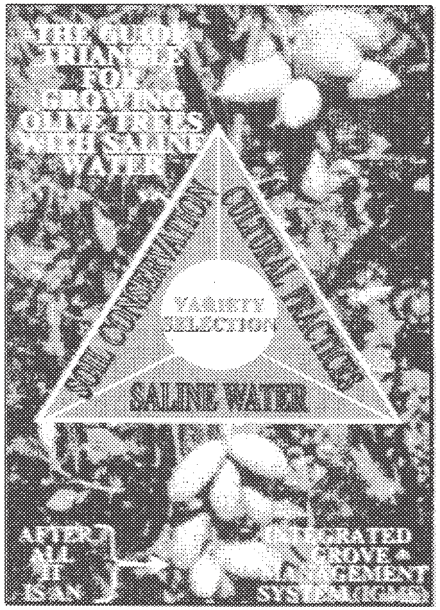


Fig 1

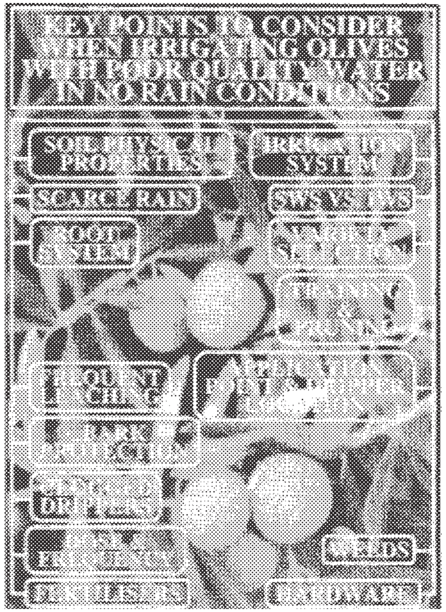


Fig 2

protected the soil from wind erosion during the early years while root penetration and green coverage were still unable to contribute to soil conservation.

In some spots of the shallow depth hardpan and prior to backfilling, a gravel pack of 120 to 150 mm thick is provided at the bottom and periphery of the pits as per the procedure of Fig. 4. This pack has been foreseen to act as a barrier (especially when the trees are juvenile) against salts movements from the salt front backwards to the main root bulb in case of an emergency such as a clogged dripper, malfunction of the submersible pump or even during scarce rains.

The topsoil is levelled and the pits are reformed with small depressions to prevent water runoff.

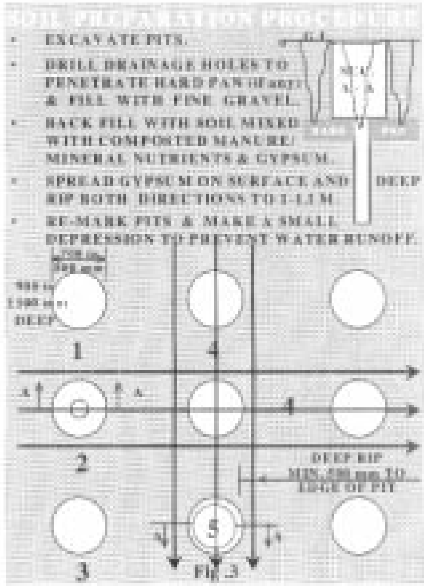


Fig 3

Irrigation management of poor quality water focusing on reducing negative impacts

The system used is drip irrigation. Since installation the author has developed a new method named "Spear Irrigation" aimed at reducing the negative impact of accumulated salts and encouraging the development of a deep root system.

Relative deepening of the olive trees' genetically shallow root system is necessary under the local conditions of the grove, as it will improve water use efficiency due to less fluctuation in soil moisture and temperature at lower depths. Improving water use efficiency will reduce salts accumulation and thus leaching requirements. Roots close to the surface are exposed to dryness and reduced activity by possible salt accumulation.

Aside from the necessity of a deep root system with the poor quality water, such a system also provides the trees with better

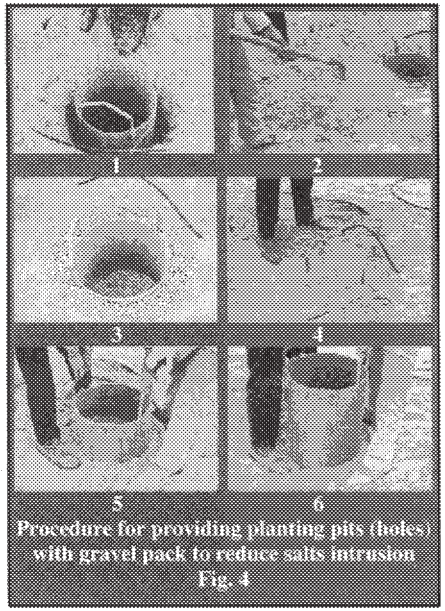


Fig 4

anchorage against winds and efficient support for heavy crops.

The Spear Irrigation system is comprised simply of a 600 mm long Low Density Poly Ethylene (LDPE) 18 mm lateral pipe. The pipe is perforated all the way through its length like a mesh and is driven into the ground at a distance of 120 to 150 mm from the trunk with an angle of 30° to 45° to the vertical. The water flows from the dripper into the buried Spear Pipe through a micro tube of 4 mm and through the perforated holes and the lower open end of the pipe directly into the root zone bulb. The upper open end of the pipe is installed above ground with 50 to 70 mm exposed to light thus preventing the roots from penetrating the small holes causing clogging of the water flow.

The advantages of the Spear Irrigation System in general and when utilising the poor quality water in specific are:

a) Reduces evaporation from the soil surface, consequently minimising water loss and build up of top profile excess salinity, which causes crusting resulting in reduced permeability.

b) Produces increased osmotic pressure close to the water bulb centre causing salts to move down and outwards from the root zone.

c) Improves water use efficiency thus reducing the amount of salts being deposited in the soil.

d) Contributes in integration with land preparation, maintenance and improvement practices in developing a deep root system with the advantages discussed above.

e) While it is a semi-subsurface irrigation system, it produces a symmetrically shaped water bulb minimally affected by environmental factors such as wind or exposure to the sunny, non-shaded areas. This symmetrical shape encourages the growth of a well-distributed root system.

f) Eliminates water runoff, which is not a major problem in itself on these soils. With this poor quality water, runoff can cause hard-to-manage salt accumulation in localised spots.

The point of water application is of paramount importance when using poor quality water. Changing this point followed by dryness of previously wetted areas, or even vice versa, can cause sudden movements of salts from high salt boundaries into the relatively salt-free root zone via capillary action, reduced osmotic pressure or salt intrusion washed in by a new point of application.

Therefore it is strictly prohibited to change this point. When changes are mandatory, like when the number of drippers needs to be increased, then it is only allowed during winter, while the roots are less active, water requirements are less and the bore water is of better quality.

With its scarcity and low rates, rain has never helped in leaching salts. To the contrary it can cause considerable damage as it moves the salts from settled boundaries (the position of which is highly managed through irrigation) into areas of active roots. During rain, irrigation must be immediately applied to keep the osmotic pressure inside the water bulb higher than those temporarily caused by the falling rain otherwise the trees might be seriously damaged.

Where to install the dripper

From experience gained through the years, while using this poor quality water, it is highly recommended to install the dripper on the southern side (northern side in southern hemisphere groves) of the trunk whenever similar water is used. This is to compensate for the accelerated dryness on this side caused by being exposed to more sunlight. Salts will accumulate more on this side restricting the root growth. The case is clearly manifested while the trees are juvenile and not shading enough ground surface.

A dripper clogged for some time could be a real threat to the survival of an olive tree with the water quality used in this 'Field Model'. Once the osmotic pressure drops inside the root water bulb, salts move backwards from the salt front, damaging the root system. Therefore the irrigation system must be subjected to strict, frequent operability inspections in addition to injecting cleaning agents like sulphuric and phosphoric acids into the irrigation network.

Irrigation strategy

Given the low water-holding capacity of the soil, the prevailing climatic conditions and the poor water quality, the irrigation strategy is characterised in general by frequent small applications on short intervals with periodically increased doses to satisfy leaching requirements.

Applying this strategy has resulted in keeping the Soil Water Salinity (SWS) at lower levels than the Irrigation Water Salinity (IWS) at all times. During summer, the values of Kc (crop coefficient), Eto (evapotranspiration rate), water requirements and water salinity are at their highest levels. To ensure the salts are continuously leaching properly under these circumstances and the efficient use of extra water, the daily irrigation cycles are applied one day as a heavy irrigation followed by a light irrigation the following day. The heavy irrigation = X/2 + 0.2X while the light irrigation = X/2- 0.2X where X = water requirements in two days.

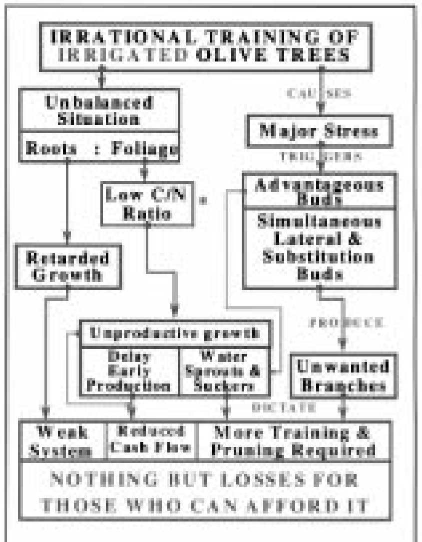


Fig. 5

* C/N = Carbohydrates to Nitrogen ratio

In winter, the normal irrigation cycle is 3 times/week. During this period all factors influencing water requirements are at their lowest values, including the TDS of the irrigation water. While the roots are in a relative resting period, an extra heavy irrigation is applied to leach and dissipate salts accumulated during the season into deep soil horizons and to fill the water bulb underlying each tree with less saline water. Three weeks before floral bud swelling, another heavy irrigation is applied, followed by 7 to 10 days of no watering.

This is done to apply some stress on the trees to enhance uniform flowering, thus leading to a better fruit set and improved yields. Uniform flowering is an advantage for uniform ripening, facilitating efficient harvesting management.

In summer, irrigation is applied at nighttime as much as possible to reduce evaporation.

Under the micro climatic conditions, and using a crop coefficient of 0.4 to 0.65 for table olives according to the physiological stage of the trees, the water consumption quantity including leaching needs per mature tree per year varies between approximately 16.5 and 21 m^3. Before reaching full green coverage (foreseen as 80%) and with varying densities, this figure reveals a water consumption per hectare of a minimum 4587 m^3 (4.6 megalitres) up to a maximum of 8400 m^3 (8.4 megalitres).

Taking an average watering of 18.75 m^3/tree/year and the 1997 production, representing the highest yield and water consumption so far, the water consumed per kilogram of fruits produced was 177.8 litres.

In the early years, while the water requirements are still low, only one Spear Pipe is provided per tree. Once the water requirements are increased another Spear Pipe is installed, followed a few years later by low discharge surface drippers installed on a lateral pipe ring which diameter varies with the canopy size ranging from 1.25 m to 1.75 m. For the new heavy density planting of 606 trees/ha, the intention is to try to restrict the application point to one spear.

Olive tree bark sensitive to salt

During the years it has been noted that the bark of the olive tree trunk is very sensitive to salt injury. Salts being moved via capillary action upwards on the lower trunk portion cause bark necrosis. The best method to control this side effect is to coat the trunk up to a height of 150 mm from the ground surface with clear polyurethane paint every second or third year.

The poor quality water used in this Field Model is very corrosive; therefore the use of special alloy material for the pump and other metallic components is a major requirement.

Managing Training & Pruning Practices as Influenced by Micro Environmental Conditions

The strategy of training and pruning must be very rational and adaptable to micro conditions taking into account the profound effect of the following factors:

a) Fully-irrigated olive trees exert higher energies, which are reflected in their higher rates of vegetation growth, alerted substitution bud, higher cropping potentials and their reduced tendency towards alternate bearing. Copying strategies applied elsewhere in the Mediterranean on rain-fed trees will result in great failure and will have negative impacts on all of the above-mentioned positive features.

b) Early and heavy crops should be targeted to pay back reclamation costs and ongoing expenditures associated with controlling the side effects of using the poor quality water.

c) Lower crotched trees are favoured as they will control evaporation losses from wetted areas leading to efficient water use and reduced build up of salts on the top soil profile.

d) In rain-fed groves, training and pruning are highly reflective by the amount of rain received during the season. If the amount is minimal, pruning should be severe otherwise neither the trees nor the fruit will have enough water. This is not applicable in irrigated groves.

e) The high light intensity on the location must be taken into account in shaping the trees. There is no need for opening the trees centres as practised in less light intensity regions.

f) There is no grazing under the trees and no intention to harvest them using mechanical shakers, therefore the time and energy for both the trees and nurturers should be saved, as there is no need to train and maintain the trees with clear trunks.

The above training and pruning strategy, under the given micro environmental conditions, encourages the free natural shrubby form of the trees with a high leaves-to-wood ratio. This form has many advantages, starting with keeping the trees at a well balanced nutrient status thus leading to early cropping, high yield production and ending with less pruning costs, while maintaining the trees at reasonable sizes suitable for hand picking. Implementing this strategy through 13 years has proved to be very efficient and most importantly, very profitable.

[Based on an ticle in Australian Olive Grower, Issue 25, January 2002].

Australian Olive Grower: A3140.

HYBRID HAZELNUTS: AN AGROFORESTRY OPPORTUNITY

GERRELD L. PULSIPHER
Visual Concepts, Inc.
SCOTT J. JOSIAH
Lincoln School of Natural Resource Sciences and Cooperative Extension
University of Nebraska
Nebraska USA

Hybrid hazelnuts offer a new agricultural opportunity — a system of woody agriculture that supplies food staples from domesticated woody perennial plants.

Hazelnut plants can produce food for ready markets, lessen the use of chemicals, and reduce the loss of top soil commonly associated with the production of annual cereal grains.

Once established, hazelnut plants yield delicious nuts for personal enjoyment or for commercial markets.

An Emerging New Crop

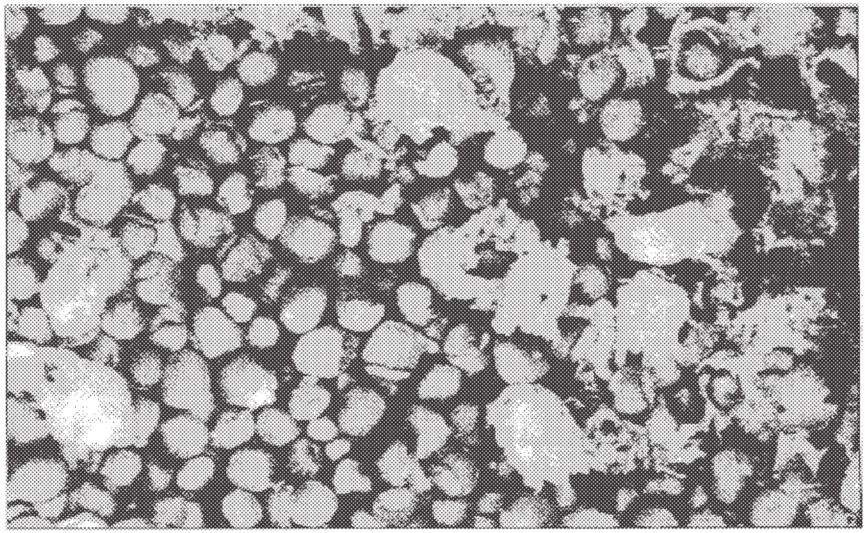
Hazelnuts (*Corylus* sp.), also known as filberts, are found throughout the world. Hazelnuts produce a sweet, tasty nut that can be used in confections, for oils, and in a wide range of food products.

Hazelnuts are a nutritious and high-protein (19%) food. Hazel oil (79% monounsaturated) is an excellent cooking oil with a long shelf life. Hazels also are an excellent source of vitamins E and B6. Meal left after oil extraction can be used as livestock feed.

The most commercially successful hazelnut species has been the European hazel (*Corylus avellana*). This species produces nuts of higher quality, larger size, and thinner shells than the two North American native species, the American hazel (*Corylus americana*) and the Beaked hazel (*Corylus cornuta*). However, the European hazel is less tolerant of cold temperatures and is susceptible to Eastern Filbert Blight.

The American species grow well over a large part of the United States and Canada, tolerate varying soils and weather, are relatively pest free, and are resistant to Filbert Blight. All hazelnuts grow in clusters, each nut surrounded by a fibrous husk or involucre.

To combine the best characteristics of several hazelnut species, plant breeders have worked to crossbreed the European hazel with its two American cousins. Research plots, like The National Arbor Day Foundation's Hazelnut Research Field at Arbor Day Farm, Nebraska,



Hybrid hazelnuts

are helping scientists identify and propagate the most successful of these cold-hardy, disease-resistant hybrid shrubs. These and other research efforts have resulted in the development of superior hazelnut cultivars that may be suitable across much of the United States.

How to grow Hybrid Hazelnuts

As an orchard

Since hybrid hazels may live for 30 years or more, it's important to choose a site well suited for their growth and care. Best nut production requires full sun, with recommended spacing of 2.5 metres apart within each row, and 4.5 m between rows. Hazels have deep, fibrous roots and grow well in most soils. Avoid very heavy clays, shallow hardpan, and marshy soils. These shrubs dislike having overly wet roots, so make sure the soil has good drainage. Because warm days early in the season may cause premature blooming, avoid planting on land with southern exposures in regions where frost may be a problem.

As a windbreak or snow fence

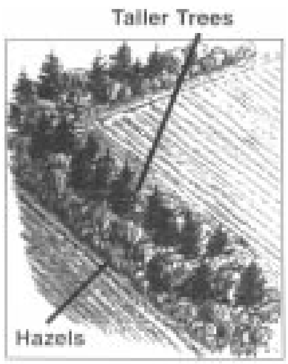
Because hazelnut bushes are quite dense, they

Research trials located across the Midwestern United States and Canada demonstrate the performance of hybrid hazelnuts can make an effective income-producing windbreak in both summer and winter. Most hybrid hazelnuts will reach a maximum height of 2.5-4.5 m. They are most effective in blocking wind when used along with taller trees. Make sure the taller tree rows are at least 4.5 m away and will not shade the hazels. A living snowfence can be created using one or two rows of hazels, with plants staggered to create a denser barrier to wind and blowing snow. This kind of snowfence is cheaper to maintain than lumber or metal ones, provides year-round wind protection, and supplies food and cover for wildlife.

Hybrid hazelnut bushes

In riparian forest buffers and alley cropping

Riparian forest buffers consist of rows of trees, shrubs and other vegetation planted near streams or lakes to trap soil, chemicals and nutrients, store water, reduce floods and erosion, provide habitat for wildlife, and enhance recreational opportunities. Used in a riparian forest buffer, hybrid hazels help provide all these environmental benefits, while at the same time producing additional income for landowners through nut sales.

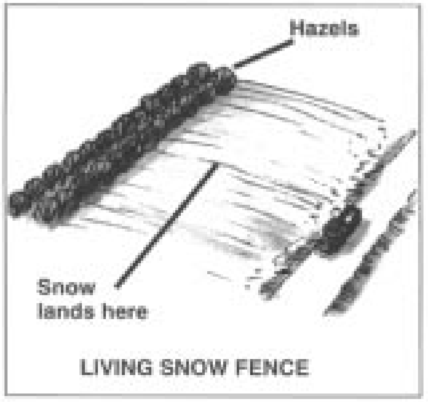


Windbreak

Alley cropping uses widely spaced strips of trees or shrubs, with annual crops grown in the alleys between the strips. Hazelnuts grown in alley cropping strips can provide additional income from annual nut harvests.

For odd corners and other uses. . .

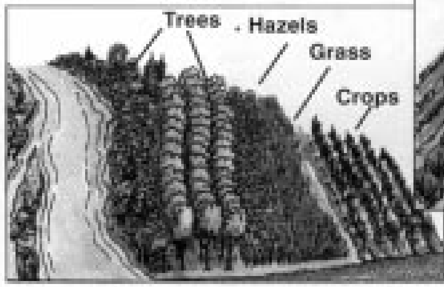
Hazelnuts may provide an income-producing capability for small, difficult-to-farm parcels of land, such as those created by pivot irrigation systems, or when unusual topography is unsuited for cultivated crops. In whatever location they are planted, hazels provide year-round cover for many kinds of wildlife.

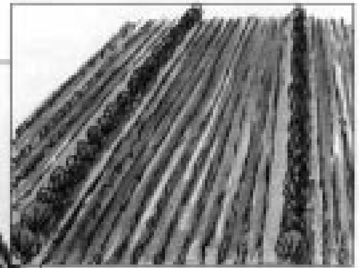


Planting hazels

Spring is the best time to plant seedlings. Be sure to use a reputable nursery who can ensure that you are getting hazelnut cultivars best suited to

Riparian forest buffer





Alley cropping

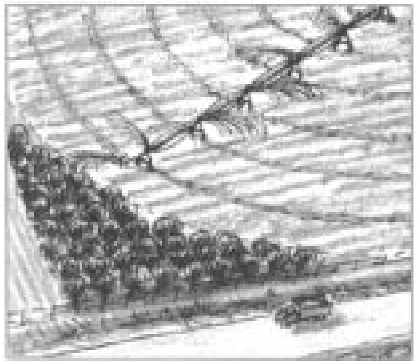
your region's soils and climate. Hybrid hazelnuts are generally supplied as seedlings, rooted layers, or grafted seedlings. Some nurseries ship their hazelnut plant material in the early spring while the plants are still dormant. Others ship leafed-out seedlings in containers.

If you can't plant immediately upon delivery, place dormant plant material in a refrigerator and store at a temperature of 3 °C. Keep leafed-out seedlings in light shade at ambient temperatures, but keep from freezing or drying out. Mid-summer planting increases plant stress and reduces growth and survival.

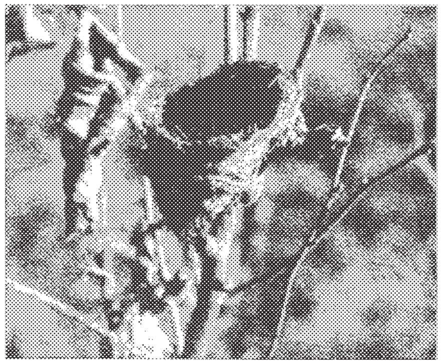
For bareroot seedlings, dig a hole that is large enough to easily accommodate the roots. Turn the soil and break up any large clods. Rough up the sides of the hole to aid in root penetration. For tubelings (containerized seedlings), check with your nursery supplier for the appropriate planting methods and tools.

Plant the hazelnut plant no deeper than it was grown in the nursery. Do not plant too deep, nor too shallow! Back fill with the soil taken from the hole. Take care to keep the seedling in an upright position and after filling, firm the soil around the roots. Avoid crushing the root mass, but also avoid leaving large air pockets next to the roots.

Water immediately to settle soil and remove air pockets.



Pivot irrigation corners

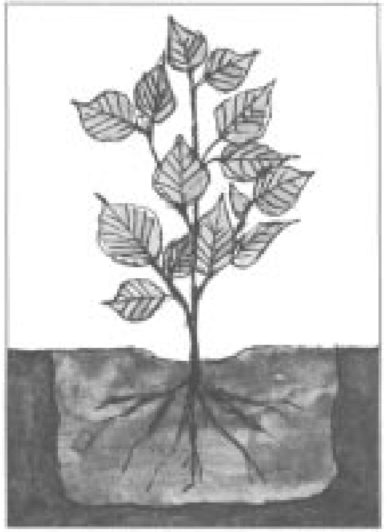


Hazels enhance wildlife habitat

Caring

For the first year or two, most of the energy of your seedlings will go into the production of roots. When the plants are well established and anchored, you should see a surge in growth, followed by the development of flowers and nuts in 4-5 years. Typical annual growth rates are 10-15 cm in the first year and 45-60 cm once established.

Cultivate shallowly, 5-8 cm per year for the first 2 or 3 years. Very little pruning should be required, and it is normal for root suckers to appear and form a multistemmed bush. It is very important to keep the area around the hazelnut weed free out to about 1 metre. Newly planted hazels also may need supplemental water during the first 1 or 2 years. And because of their large leaves, establishing your hazelnuts in an area protected from wind will reduce water stress and leaf shredding, and increase survival and growth.



Plant hazel seedlings at the same depth as when they were grown in the nursery

Tending three-year-old hazelnuts

Hazels are relatively pest free. Although they are not favoured as a deer browse, deer will sometimes feed on fast growing plants. Consider wire barriers or repellants.

Mice, voles and rabbits may eat stems in winter, but the plants recover very quickly. Keeping grass short can discourage mice. Older hazel shrubs can be invigorated by pruning to the ground to encourage growth of new stems. Squirrels and chipmunks will steal nuts, particularly if planted near woods, but not as much if planted in open fields.

Insects cause few problems for hazels, but several kinds of weevils attack the nuts. Bud mites

can be especially serious. The main disease of concern is Eastern Filbert Blight, which attacks the susceptible European species. Several American hybrids are resistant to this malady.

Studies conducted in Minnesota have shown that the fall application (early September) of 15-5-20 fertilizer at a rate of 100 gm/sq m to established hazels resulted in consistently better nut crops and more vigorous bushes. New plantings generally do not require fertilizer for the first several years.

Harvesting

With good care of vigorous seedling stock (proper planting at the right time, vigorous planting stock, adequate weed control, and supplemental watering during the first few years), hybrid hazels will begin to yield nuts after 4 or 5 years.

Preliminary data from test plots in Southeast Minnesota indicate that an average hectare may produce 900-2,200 kilograms of nuts per year, depending on the cultivar, weather, and other factors. Nut production can be cyclical, with heavy production one year and lighter production the next. Full sun is needed for maximum production.

Harvesting and processing hazelnuts can be labour intensive. Hazelnuts need to be removed from the involucre (husk) before going to market. Harvesting and processing machinery specific to bush-type hazelnuts is still in the developmental stages.

In much of the United States, successfully growing hybrid hazels for commercial nut production faces several challenges, including development of cost-effective harvesting and processing methods, and insufficient regional testing of hybrid hazelnut cultivars. Until recently, there were no commercial hazelnut plantings east of the Rocky Mountains, which means that development of networks of local markets or purchasers is still in its infancy. Producing, harvesting, processing, and marketing hybrid hazelnuts will clearly require patience and ingenuity.

Markets

Hazelnuts already have significant national and international markets. Most commercially-grown hazelnuts are used in chocolate confections; added to cereals, cookies, breads, and other staples; sold as roasted and salted nuts; and made into flavourings for products ranging from hazelnut oils, coffee, syrups, and even beer.

Oregon is the major producer of hazelnuts in the United States. In the summer of 2000 the average wholesale price for unshelled hazelnuts (produced in Oregon) averaged around US $1.65 per kg. Shelled hazels from Turkey were running about $3.20, and shelled nuts from Oregon ranged from $4.00 to $4.40 per kg (UNL, 2000). Shelled hazels are generally sold for roasting or as chocolate covered hazelnuts packaged in decorative boxes and tins. A recent market assessment for hybrid hazelnuts in the Midwest indicated they are especially suitable for confectionery applications.

Hazelnuts also can be an important and unique component of a pick-your-own orchard. Being shrubs, they are easy to pick, and the nuts are relatively easy to crack and eat.

Selected Resources

- Badgersett Research Farm: http:// www.badgersett.com/#anchorl56234
- Grimo Nut Nursery: http:// www.grimonut.com
- Forest Farming. 1984. Douglas, JS and R A de J Hart. Intermediate Technology Publications, Exeter, UK.
- Hazelnut Market Research Report. 2000. Univ of Nebraska - Lincoln UNL Food Processing Center. Lincoln, NE.
- Hazelnuts. In: Fruit Breeding, Vol. Three: Nuts. 1996. by Thompson, M.M. Lagerstedt, H.B., and S.A. Mehlenbacher. Janick J. and Moore J.N. eds. Wiley & Sons.
- Income Opportunities in Special Forest Prod ucts: Self-help suggestions for Rural Entrepreneurs. 1993. Thomas, M.G. USDA Forest Service, Ag. Info. Bulletin 666
- Market trends and marketing consideration for hazelnuts. 1991. Ricks, D. and Cely P. Staff Paper No 91-34. Michigan State University, Dept. of Ag. Economics. East Lansing MI.
- Northern Nut Growers Association: http:// www. northernnutgrowers . org
- Oregon Hazelnut Industry Web site: http://www.teleport.com/~hazelnut/ index.htm
- Oregon Hazelnut retailers: http:// www.hazelnut.com/store/order.html
- Positioning Hazels for Large-Scale Adoption. 1998. Pellett, H.M., Davis, D.D., Joannides, J.L. and J.J. Luby. University of Minnesota. St. Paul, MN.
- The Hazel Tree. 2000. Farris, C. Northern Nut Growers Association, Townsend, DE
- Tree Crops:A Permanent Agriculture. 1929. Smith, J.R. Harcourt, Brace, & Co.

Photo credits: The National Arbor Day Foundation, Cheryl Richter, Philip Rutter, Nebraska Forest Service, Scott Josiah.

[Based on a National Arbor Day Foundation (USA) publication, 2001]

[Metric conversions by the Tree Crops Centre].

GENETIC AND PRODUCTION IMPROVEMENT OF GEVUINA AVELLANA IN CHILE:

SELECTED CLONES FOR NUT PRODUCTION

F. MEDEL

Instituto de Produccion y Sanidad Vegetal, Universidad Austral de Chile
PO Box 567, Valdivia, Chile.
<fmedel@uach.cl>

Introduction

Gevuina avellana Mol. (Gevuina, Gevuin, Chile Nut, Chilean Hazelnut) is a plant species of the Proteaceae family, constituting a Chilean native monospecific genus. It is found between latitude 35° and 44° S, from sea-level to 700 m (Donoso, 1998; Medel, 1987).

An evergreen tree, it grows under the influence of a temperate maritime climate in a wide range of temperatures and rainfall with a good frost resistance (Fig. 1). Adapted to diverse types of well drained soils and a range of organic matter content, Gevuina has many possibilities to make it an excellent candidate for marketing, including edible nuts (raw, dehydrated, roasted, salt and roasted), products for the food industry in chocolate, cakes, and pastries, deoiled flours, and table oil. It has pharmaceutical uses, and the wood is suitable for timber production. Other options are its ornamental beauty, and pollen and honey production from bees activity (Medel and Medel, 2000).

Genetic and productive improvement programme

With the purpose to study Gevuina and to promote its use, a programme of 'Genetic and Productive Improvement of Gevuina' started in 1970, with three research lines: a) the development of genotypes with high quality and yield of edible nuts; b) selection of superior clones based on the food composition of the nut (specially in fibre, minerals, fatty acids, amino acids, vitamins and sterols) with nutritional, cosmetic and pharmaceutical applications; and c) 'plus trees' with suitability for planting as a forest tree and for timber production (Medel and Medel, 2000).

The central hypothesis of this work was that it would be possible to select clones within the genetically diverse native population with a great productive adaptability in plantation conditions. The concept of 'productive adaptability' has been important for the commercial development of single species in Chile and elsewhere, and takes into consideration high productivity and quality germplasm, with a minimum technological and operational inputs for production in a sustainable environment (Medel, 1990: Medel. 2000 Medel. 2001 a).

Selected clones for nut production

The selected six clones were from 119 accessions evaluated in the years 1977 to 2000 (Fig.3). These promising 'VAX series' clones showed good productivity under conditions of temperate climate (frost resistance), lack of summer rainfall (water stress) and soils of low natural fertility and good drainage (Medel, 1988; Medel, 2001b). The clones began their production between the 3rd and 5th year of age, arriving at their productive peak between the 8th and 10th year, after which production levelled off.

Fig. 1. Nuts, flowers, and foliage of Gevuina in summer

Harvest is carried out in February and March of each year in Chile, gathering from the ground almost 80% of the nuts over 15 to 20 days. The nut is a black lignified drupe, with a thin easy-to-peel, smooth shell. The kernel is cream-white with a crisp texture, rich flavour and good taste (Figs.4, 5 and 6).

The main characteristics of the six clones are shown at Table 1, according to their yield, nut characteristics (NIS: nut-in-shell, kernel, shell) and vigour of the trees. Table 2 lists the total yields and the kg/tree of high-weight nuts (>2.5 g), with a good proportion of kernels weighing over 1.0 g, and therefore of commercial value for edible nut production.

Fig. 2. Gevuina nuts and nut meal with cake and chocolate mix

The note on tree vigour is important to arrange them in the orchard for the most efficient use of land. Several clones in the same orchard are important for good cross-pollination by bees for a high fruit set. Considering densities and plantation arrangements

Table 1. Nut production characteristics and tree vigour of six selected Gevuina VAX clones

Characteristics	VAX Clones					
	21	33	42	43	53	64
NIS						
Yield/tree	8.07	20.53	19.93	24.48	24.63	33.72
Nuts (Nº/kg)	361	460	413	468	378	460
Weight (g)	2.77	2.17	2.42	2.13	2.64	2.17
Width (mm)	17.50	17.20	17.30	16.80	17.20	17.40
Length (mm)	20.70	19.60	20.20	19.10	19.00	20.00
Form (W/L)	0.84	0.87	0.85	0.87	0.90	0.87
KERNEL						
Weight (g)	1.00	0.95	0.87	0.80	0.95	0.80
Weight (%)	36	44	36	38	36	37
Size (W)	11.90	12.20	11.70	11.40	12.00	11.70
SHELL						
Weight (g)	1.87	1.23	1.56	1.33	1.71	1.37
Weight (%)	64	56	64	62	64	63
Thickness (mm)	2.80	2.50	2.80	2.70	2.60	2.85
Tree vigor	L-M	M	L	M-H	M-H	M-H

L: low vigor : 3.5 - 4.0 canopy width
M: moderate : 4.0 - 5.0 canopy width
H: high : 5.0 - 6.0 canopy width

Table 2. Total yield and superior nuts from trees of selected Gevuina VAX clones

VAX Clones	Total yield (kg/tree)	Nut >2.5 g (kg/tree)
53	24.63	14.53
33-42-43-64	24.66	5.98
21	8.07	5.97

Table 3. Yield per hectare at peak production of six Gevuina VAX clones with two plant layouts

Clones	NIS avg. (kg/ha)	Kernel avg. (kg/ha)
43-53-64 (4.0 x 6.0 m = 416 trees/ha)	11,485	4,247
21-33-42 (3.0 x 5.0 m= 666 trees/ha)	10,773	4,235

according to vigour of plants in relation with the six selected clones, at Table 3 the mean yields per hectare of NIS and kernels for two combinations of clones are shown.

These values are important if they are compared with other species (NIS) such as Hazelnut (*Corylus avellana*) and Macadamia, with values of 2.0 to 4.8 tonnes (Baron et al., 1985) and 2.0 to 9.0 tonnes (Halloy et al., 1996), respectively. The kernel yield can be considered also as high, and the fraction above 1.0 g, similar to that in important cultivars of hazelnut (Manzo and Tamponi, 1982), is attractive in both clone combinations.

It is possible that yield and nut quality can be modified under the local conditions of other geographical places. Nevertheless, the productive adaptability of these clones was tested under elementary orchard management. In fact, the trees were allowed to grow freely, without fertilization or pesticides or extra irrigation to overcome the summer lack of rainfall, all this with the purpose of proving their productive adaptability. The only orchard management was the mowing of the ground surface during summer to facilitate crop harvesting.

Additionally it is possible to expect good results especially in relation to temperature limitations of other subtropical Proteaceae, like Macadamia. The frost resistance of adult plants of Gevuina and the fact that flowering, anthesis, pollination and fruit development are concentrated during February (summer), permits a good development of nuts and harvest at the following year, 12 months after pollination.

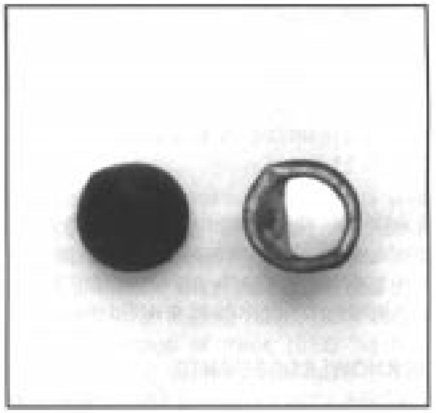
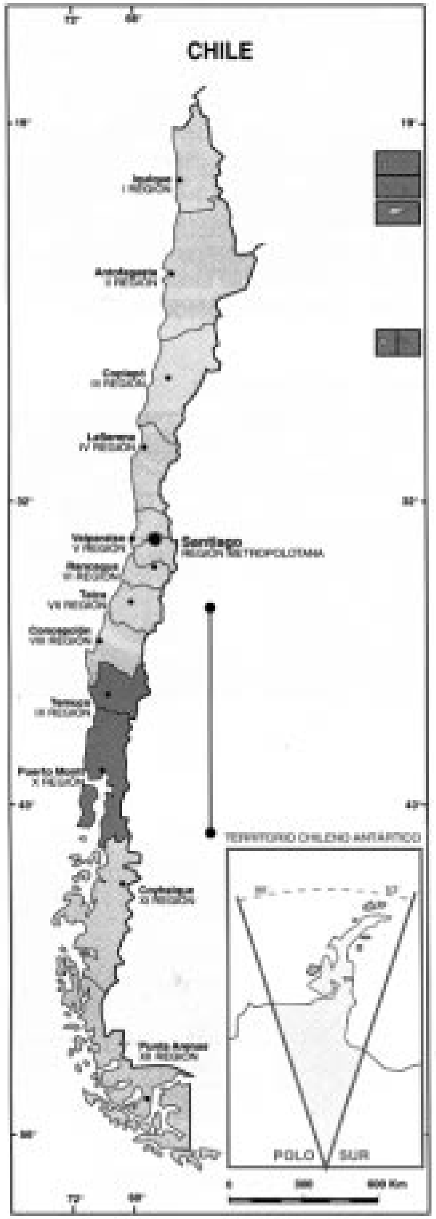


Fig. 6. Big nuts with good flavour and taste is one of the main objectives of the Gevuina genetic amd production improvement program



Geographic distribution of Gevuina in Chile (bar at right) and origen of the first selected VAX clones (map marked area)

Fig. 3

Fig. 4. Different clones of moderate vigour in Valdivia, Chile

In summary, these results show that clonal selection in a native plant with a wide variation in respect to climate and edaphic diversity has worked well. The resulting clonal selections represent a diverse gene pool that will allow further advances in the genetic improvement of Gevuina. A similar concept was presented by Reid (1995) for the wild Eastern Black Walnut, and recently the clonal selection method was used with success within cultivars of Hazelnut (Islam and Ozgoven, 2001; Valentini et al, 2001).

Conclusions and prospects

The previous considerations allow to identify genetically six clones in the series VAX (21, 33, 42, 43, 53, and 64) and to register them as protected cultivars at an international level for commercialization.

In addition, several vegetative propagation techniques (plant tissue culture, cuttings, budding and grafting, with selected rootstocks; Medel and Medel, 2001) are available for growing selected clones (Fig. 7). This first step permits to continue with more vigour the research and development programme of Gevuina.

It is considered essential to enlarge the relevant genetic resource base to cover all their biodiversity area. The techniques of orchard management for the better-quality nuts are critical for commercial production. This is especially important for the soil-water-plant relationship, proteoid root considerations, tree structure management, and harvesting systems.

Work carried out in relation to phytochemical products from the nuts, concerning the nutritional, cosmetic and pharmacological potentials of Gevuina, will be presented in a later paper.

Fig. 5. A young plant of a selected clone showing a high nut yield

A wide variety of products, plus an adequate marketing strategy, would permit this species to reach a promising position among other nuts at a world level.

Acknowledgements

Fruvax Ltda. (Valdivia, Chile) gave the grant to develop the research programme on *Gevuina avellana* Mol. accessions and clones.

References

Baron, Ll., Riggert, C., Stebbins, R.L. and Bell, S. 1985. Growing Hazelnuts in Oregon. Oregon State Univ. Ext. Serv. Ext. Circ. 1219:19.

Donoso, C. 1998. Chilean Trees Identification Guide. CONAF, 4 ed. Marisa Cuneo. 116 pp.

Halloy, S., Grau, A. and McKenzie, B. 1996. Gevuina nut (Gevuina avellana, Protaceae), a cool-climate alternative to Macadamia. Economic Botany 50(2): 224-235.

Islam, A. and Ozguven. 2001. Clonal Selection in the Turkish Cultivars Grown in Ordu Province. Acta Horticulturae: 203-208.

Manzo, P. and Tamponi, G. 1982. Monografia di cultivar di nocciouolo. Inst. Sperimentale per la Frutticoltura, Roma. 62 pp.

Medel, F. 1987. Arboles Frutales: situacion y potencial en el Sur de Chile. Universidad Austral de Chile y Corporacion de Fomento de la Produccion. 59 pp.

Medel, F. 1988. Fertilizacion y nutricion mineral de huertos frutales en el sur de Chile. UACH-CORFO, Gerencia de Desarrollo. AA 88/59. 64 pp.

Medel, F. 1990. Fruit production research and development in the South of Chile: a twenty year experience. Agro Sur 17(2): 119-131.

Medel, F. 2000 . 'Gevuin': a New Nut for International Trade. New Zealand Institute for Crop and Food Research. 2 pp.

Medel, F. 2001a. Fruticultura en el sur de Chile. Agenda del Salitre. SOQUIMICH. pp.1007-1026.

Medel, F. 2001b. Gevuina avellana: Potential for Commercial Nut Clones. Acta Horticulturae 556: 521-528.

Medel, F. and Medel R., 2000. Gevuina avellana Mol: caracteristicas y mejoramiento genetico de un frutal de nuez nativo para el mercado internacional. Revista Fruticola 21(2): 37-47.

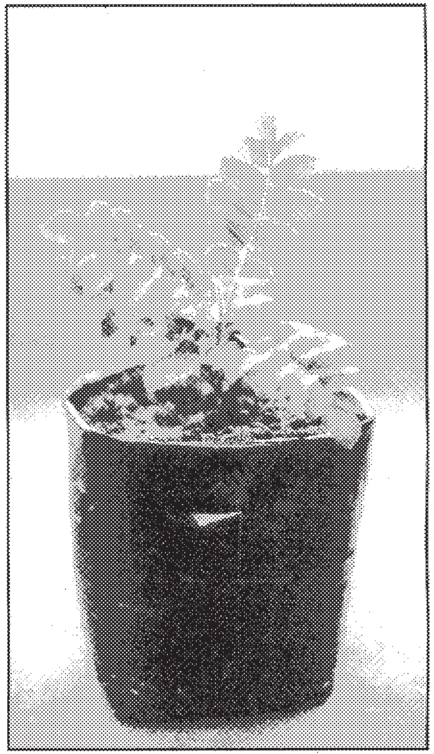


Fig. 7. A Gevuina new plant of healthy material propagated by root cutting

Medel, F. and Medel, G. 2001. Growth of Seedling Rootstocks of Gevuina avellana Mol. by soil and foliar fertilization. International Symposium on Foliar Nutrition of Prennial Fruit Plants. Int. Soc. Hort. Sci. Merano, Italy, 11 -15 Sept. 2001.1 p.

Reid, N. 1995. Eastern Black Walnut: Potential for Commercial Nut Producing Cultivars. J. Janick and J.E. Simon. In: Advances in New Crops. Timber Press, Portland, Oregon. pp. 327-331.

Valentini, N., Marinoni, D., Me, G. and Botta, R. 2001. Evaluation of 'Tonda Gentile Delle Langhe' Clones. Acta Horticulturae 556: 209-218.

[Based on an article in the FAO-CIHEAM - Nucis-Newsletter, Number 10, December 2001]

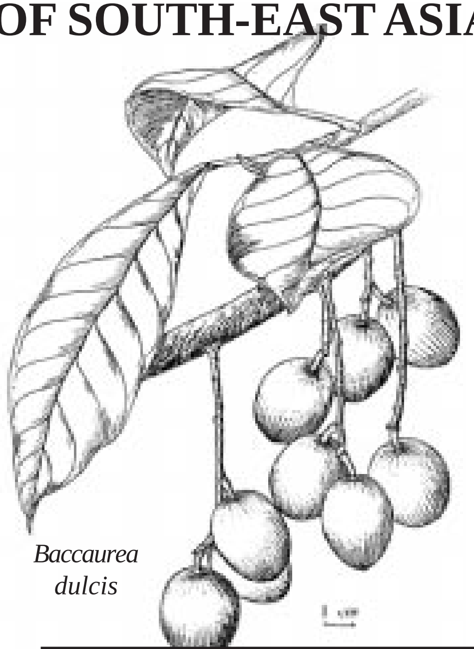
Nucis Newsletter: A3287.

UNUSUAL FRUITS OF SOUTH-EAST ASIA

Baccaurea dulcis (Jack) Muell - Arg.
Ketupa (Indonesian).

Baccaurea dulcis is a dioecious tree of 15 to 25 m high with trunk up to 75 cm in diameter. Its flowers are arranged in panicles. The fruits are round, 3 cm in diameter, yellowish green. The flesh is white and tastes normally sweet, sometimes acid. This tree is a native of South East Asia and occasionally cultivated in Vietnam, Burma, Thailand, Malaysia, the Philippines and Indonesia. The tree grows well in lowland areas.

Though it may be propagated by seeds, the length of time between germination and fruiting is not known with certainty. The plant is therefore usually propagated by marcottes. This species is plentiful both in cultivation and wild around Palembang, Sumatra. The fruits are sold in the markets and eaten fresh. This tree may also be used as a shade tree as it has a fine crown.



Baccaurea dulcis

Bouea macrophylla Griff.

Maprang (Thai), Kundang (Malay), Gandaria (Indonesian).

In appearance *Bouea macrophylla* resembles a mango tree and its height can reach 20 m The leaves are decussate, oblong lanceolate, smooth, and shining. The flowers are arranged in panicles like those of mango, the inflorescence light yellow, growing from the axils of the leaves at the ends of the young branches. The fruits are ellipsoidal, when ripe yellow or light red and juicy, with thick flesh. Some fruits have an acid taste and some are sweetish sour.

Bouea macrophylla is a native of South East Asia. It grows well at elevations from 5 to 800 m on light soils. It is now spread to

Glossary

Asinan: Fruits or vegetables pickled in a weak solution of vinegar, to which sugar, chili pepper, salt and prawn powder are added.

Dodol: Thick porridge made of flour of glutinous rice (or maize, mango cotyledons, or other starch), coconut milk and palm sugar; fruits are sometimes added to give the desired flavour.

Kuaci: Boiled and salted seeds of watermelon and rarely also of other cucurbitaceous plants.

Lalab: Side dish mostly consisting of young leaves and fruits and eaten raw (or rarely steamed) with prawn paste, chili pepper and salt together with rice.

Manisan: Pieces of fruits boiled in sugar, served dried or moist.

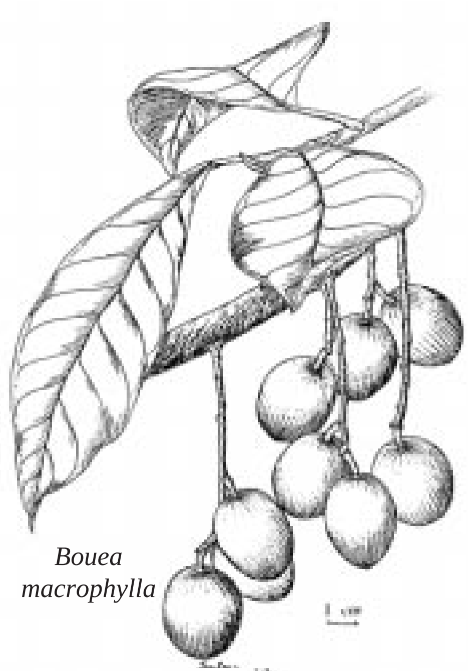
Rujak: A delicacy made of sliced or pounded unripe fruits, vegetables or tubers and eaten with prawn or fish paste, chili peppers, palm sugar, salt, vinegar and peanuts.

Selai: Dried and sometimes also candied ripe fruits dried in the sun.

tropical America. In Indonesia it is seldom grown in East Java as it is primarily a tree of wet areas.

Propagation is normally effected by seeds. Sometimes it is also propagated by marcottes The cultivated form has been selected for its sweet fruits. The flowering season lasts from August to September and ripe fruits are borne in December and January.

The sweet fruits can be eaten fresh after being peeled, but a great deal of the ripe fruits are used for the preparation of syrup and fruit juice. The unripe fruits are used in making rujak and asinan. Sometimes it is also employed as a substitute for sour lime or tamarind. The wood can be used as a building material and is favoured by wood carvers. The sheath of the keris or Indonesian dagger is often carved from its wood.



Bouea macrophylla

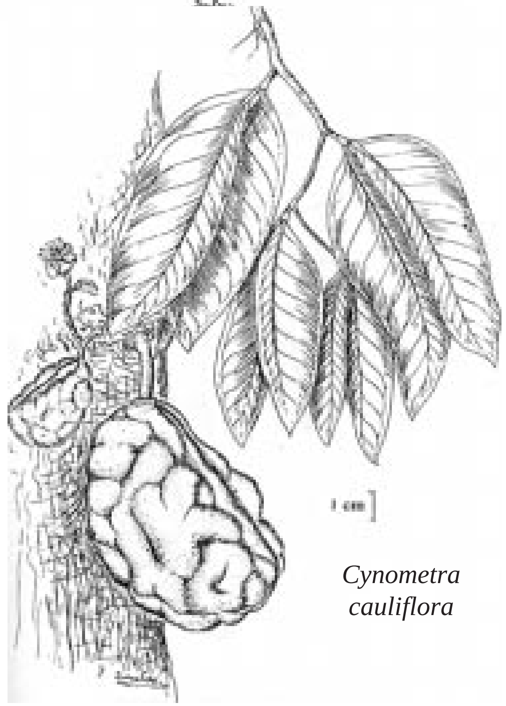
Cynometra cauliflora L.

Nang-ai (Thai), Namnam (Malay, Indonesian).

This species is a tree reaching 12 m high, with warty trunk. Leaves are paired, shining and pink or whitish red when young. Flowers, arising from the trunk, are small, reddish white or pale pink. Fruits are olive brown, wrinkled and almost kidney shaped. The flesh is juicy, fragrant, pale yellow and tastes sourish-sweet. Normally the fruits contain only one seed but sometimes there are fruits with two seeds.

This plant occurs naturally in India, Malay Peninsula and Indonesia. It is also grown in other parts of South East Asia. It grows well in lowland areas with fertile soils. It prefers open and flat places. This plant is usually grown from seeds. It can also be propagated vegetatively by marcotting or grafting. The tree flowers in June to September, while ripe fruits are borne in August to November.

Ripe fruits are eaten fresh. The fruit pulp is commonly used for rujak and asinan. As the



Cynometra cauliflora

plant has thick foliage with attractive pink or whitish-red colour, it can be planted as an ornamental plant.

In Celebes [Sulawesi] there are two cultivars, one producing sweet fruits and the other sour fruits. Unfortunately this species is now becoming rare because economically it is as yet unimportant.

***Diospyros philippensis* (Desr.) Gurke.**

Ma-rit (Thai), Buah mentega (Malay, Indonesian), Kamagong (Philippines), Butter fruit (English).

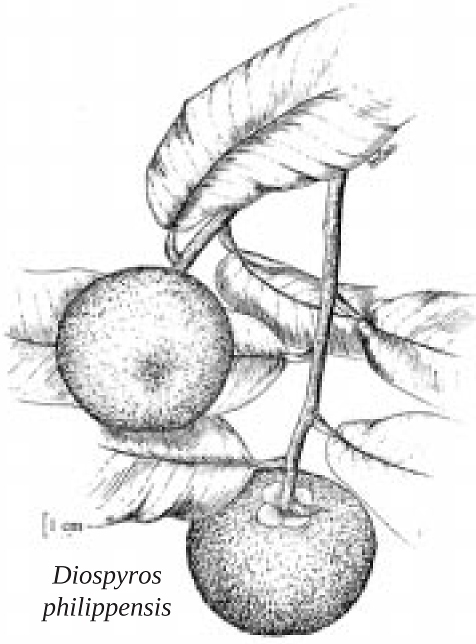
Diospyros philippensis is a dioecious tree reaching 15 m high. It has a dense round crown. Flowers are yellowish white and pleasantly fragrant. Fruits are round, somewhat flattened on either end, with pale red or yellowish orange skin covered with reddish fine hairs. Fruits have a butter-like smell, and contain brownish seeds. There are also varieties without seeds. Its place of origin is the Philippines, while in Indonesia it is only rarely planted in courtyards. The best place for its growth is well-drained damp soils. It grows well at elevations of 10 to 800 m.

Propagation for the seeded varieties is effected by seeds. It can also be propagated by marcotting and grafting. The latter modes of propagation are mainly applied to the seedless varieties. It flowers in March to May and the fruits become ripe in September. Ripe fruits can be eaten fresh. As it has thick foliage the tree can be used as a wayside shade tree. In the Philippines the wood is used for making combs and household utensils.

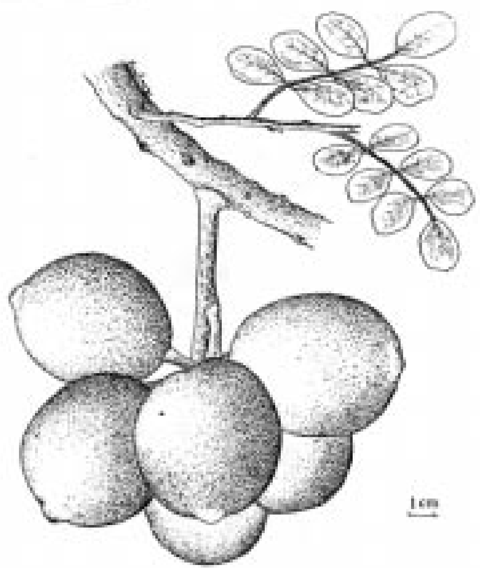
***Feroniella lucida* (Scheff.) Swingle**

Ma-khwit (Thai). Gelingga (Malay), Kawista (Indonesian), Wood apple (English).

This species is a tree reaching 15 m high, with spiny stem . Its leaves are small, dark green. Fruits are in clusters of 5 to 9, with a smooth and glossy skin which is nearly as hard as a coconut shell. Seeds are small, flattened, yellow to light



Diospyros philippensis



Feroniella lucida

green. This plant is a native of India and Sri Lanka, usually growing below 300 m alt. It prefers dry regions, sometimes growing on nearly barren lands. It is common in coastal areas in Central and East Java, in association with teak.

Propagation is effected by seeds. This plant has been used as a rootstock on which different kinds of citrus were grafted. It flowers in November to December, but it will not bear ripe fruits until July and August. Its fruits are not as popular as citrus or rambutan, but in places where the plant exists the ripe fruits are made into a refreshing drink by the villagers. Unripe fruits, which are astringent,can be used for making rujak. The wood is used for fuel, while the gummy exudate from the bark can be used for making ink. Flowers and leaves are used as a drug for improving the digestion.

Flacourtia inermis* Roxb. var. *inermis

Rukam masam (Malay), Lobi-lobi (Indonesian), Thornless rukam (English).

This species is closely related to *Flacourtia rukam* Z. & M. It is a thornless tree reaching 15 m high. Its leaves are oval, the young ones reddish purple. Fruits are small to medium, spherical, dark red when ripe, sourish to sweet, sometimes pungent, many seeded. The tree starts flowering in January and February and it bears ripe fruits in May to July. Its place of origin is probably Malesia. Nowadays it is widely planted in village gardens in Malaysia, Indonesia, the Pacific Islands and other tropical areas. It thrives well in all kinds of soils and grows below 1300 m alt.

Propagation is often effected by green budding into a stock tree and by marcotting. It can also be grafted onto *Flacourtia rukam*. The ripe fruits are used in making rujak, syrup, pickles and sweets and it can be stored dried or tinned. When consumed raw the fruits taste sourish and pungent. The trees are often grown as ornamentals as well because of their beautiful young leaves.

Flacourtia inermis

***Myristica fragrans* Houtt.**

Pala (Malay, Indonesian), Nutmeg (English).

Myristica fragrans is a medium sized tree reaching 18 m high with a conical crown, dioecious. Its flowers are small, pale yellow. The fruits are golden yellow, obovoid, resembling apricots, thick skinned, strongly aromatic. The shiny brown seed is covered by a bright red branching aril This well-known plant is native to the Moluccas and now widely grown in India, Malesia, Australia and the Pacific Islands. It is grown in open areas with a high relative humidity or humid areas near the coast. It prefers light but fertile soil below 500 m alt.

This species is propagated by seeds, which cannot be stored very long without losing their viability. Seedlings require shading and a plant raised from seed normally will fruit after 8-10 years. It can be grafted onto other species of *Myristica*.

The fruits are often used in making asinan or rujak. It is also comfited into manisan. The seeds and arils yield the well-known spices, nutmeg and mace respectively, used in cooking, medicine and the perfume industry. The best quality nutmeg comes from Banda Island.

Myristica fragrans

***Syzygium malaccense* (L.) Merr. & Perry**

Chom-phu-sa-raek (Thai), Jambu merah (Malay), Jambu bol (Indonesian), Malay apple (English).

The Malay apple is a medium sized tree reaching 15 m high, with dark green leaves and a dense crown. Its flowers are reddish pink and scented. The ripe fruits are globose, whitish to dark red, containing one large seed.

Syzygium malaccense

This species is native to the Malay Peninsula but now it is widely grown in the Pacific Islands, India, Peru, Brazil, Mauritius and Jamaica. It grows well below 1200 m alt., and occasionally occurs in secondary forest in association with *Syzygium zollingerianum (*Miq.) Amsh.

It is propagated by seeds or marcotting. It fruits in August to September. If compared to other *Syzygium* fruits, Malay apple is the most expensive.

The fruits are consumed fresh or used in making rujak and asinan.

[The above is a selection of 8 fruits from the 59 in the book “Fruits”, published by the IBPGR Secretariat, Rome, 1980. This was an English version of the Indonesian book “Buah-buahan”, prepared by the Proyek Penelitan Potensi Sumber Daya Ekonomi - LIPI (Publication Series no. SDE-41, Bogor, 1977].

SUPERHERO SOIL RESTORERS: WORMS AND MICROBES IN ACTION

PAUL STORER
EcoGrowth International Pty Ltd
Perth, Western Australia
<info@ecogrowth.com.au>

"I doubt that there are many other organisms that have played such an important part in the history of the world as these lowly organisms " — Charles Darwin

Introduction — soils are dead, soils can be alive

In 1881, Charles Darwin was talking about microbes and earthworms when he published an insightful paper entitled "The formation of vegetable moulds through the action of earthworms" as the culmination of his 40-year study into earthworms. He recognized the earthworm's ability to improve the fertility of the soil in which they live, thus making it suitable to sustain other kinds of life (such as plants and animals).

Earthworms and microorganisms are now playing an ever increasingly vital role in Bioremediation, and in creating and maintaining sustainable systems in which we are to live. As we launch headlong into the 21st Century we must reassess our thinking and our methodologies. Soil quality has been poorly understood, and is often neglected, and yet the Biodiversity of the soil is vital to ecological health.

A poor soil structure can result in the need for greater and greater amounts of nutrients and a greater amount of water, to produce the same level of plant health, versus soil with a good soil structure. Soil structure can be modified and improved by the action of insects and microbes, and by natural earthworm tillage coupled with essential mineral rock application and better water management practices. In combination with beneficial microbes, each earthworm acts as a gifted micro-plough that can be left with minimal supervision, and yet will tirelessly 'get on with the job'.

However, the chemical contamination and mechanical tilling basis (1, 2, 3) of our agricultural systems and the poor waste management practices (land fill, raw sewage dumping etc) that have been adopted by 'modern industrialized man' (particularly over the last 50 years) have led to destruction of our topsoils.

No longer can we, as transient 'caretakers' of this planet, continue with the current schemes of managing our population explosion and the resulting urban sprawl and subsequent waste; or our traditional agricultural, economic or even political systems. Even at this time, these institutionalized systems are already collapsing and inevitably will destroy themselves because they are not designed holistically (short-term economic gain rather than long term economic and environmental viability), as substantiated by the onset of many gut-brain related diseases (such as Autism, Chronic Fatigue Syndrome, Irritable Bowel, Depression, antibiotic resistant pathogens etc); or the BSE (mad cow disease) disaster that is set to ravage the health and economies of Europe. Add to this the wanton and massive environmental damage caused by world-wide deforestation, increasing soil salinity and desertification, and the pollution and toxification of our soils (4, 5, 6). We are also drowning in our own human waste... with the resulting increase in toxicity, heavy metals, and pathogens.

This ecological disaster results in dead soils. All of this eventually has to lead to belated (but necessary) global changes to agricultural and waste management practices and the adoption of more sustainable and 'green' approaches — starting with the treatment of human and animal sewage in composting worm/microbe type recycling toilets; and the restoration of healthy, living soils.

Nutrients in Vermihumus compared to the surrounding soil from which they came

Nutrient	Vermihumus kg/ha	Soil kg/ha
Carbon	194,000	89,200
Nitrogen	12,180	7,950
Phosphorus	320	45
Potassium	1020	160

(From Graff, O: 1971 Annual Zool. Ecol. Anim. Special Publication 4, p 503-512. Soil had 4% organic matter.)

So what's the answer?

Add Worms and Microbes — Promote 'Global WORMING'.

The key lies in restoring sustainable healthy 'alive' soil systems — produced and maintained as they have been in nature for millions of years — by earthworms and microbes!

Why Earthworms?

Earthworms are by far the best way of processing many types of organic waste (from vegetable matter to animal manures and heavy metals). They can feed on dead organic material, which they convert into vermihumus (also called worm casts, or vermicast), Nature's best organic fertilizer and soil conditioner (7). Vermihumus is an important fraction of fertile topsoil and is a mixture of beneficial microorganisms, essential rock minerals and 'transformed' organic matter in a form that plants can more readily access (8); and it may also contain worm cocoons (eggs) and small worms (9). Earthworms have evolved into the fastest natural composters — each healthy adult composting earthworm can convert waste equivalent to its own body's weight in approximately 48 to 72 hours!

Vermihumus materials:

(1) Contain more bio-available organic plant nutrients, humic acids, and plant growth factors, etc, than any composted materials or factory-made fertilizers.

(2) Are pH neutral, therefore will not burn plants.

(3) Have no negative environmental impacts.

(4) Are non-toxic to living things and are sate to handle.

(5) Will not harm ground water or waterways.

(6) Do not attract pests such as flies.

(7) Hold up to ten times their own weight in water, dramatically reducing water consumption.

(8) Concentrate beneficial microbes up to 1000-fold.

(9) Can be diluted up to 90% with only a small decrease in effectiveness.

The organic materials that vermihumus are made from are composed of minerals in exactly the right ratio required to produce and sustain growth. The castings will therefore contain exactly the right natural balance required for vigorous healthy growth. However, in vermihumus the plants do not have to seek the minerals out, they are immediately and readily available. A major feature of these castings is that they do not smell.

Earthworm colonies automatically congregate where the organic waste is in greatest supply, and hence they are also self-sustaining. By exposing large numbers of specific species of earthworms to large quantities of organic waste in a worm farm, you are doing the same as nature, but in a controlled environment. Removing the castings from the worm farm and applying them to your soil will have a similar effect as continuously having an army of earthworms and microbes. As the soil becomes healthier, earthworms can be seeded from the worm farm.

Earthworms cannot harm the wider environment — in fact quite the opposite. Major scientific research studies are now showing that earthworms, in conjunction with beneficial microbes, have an

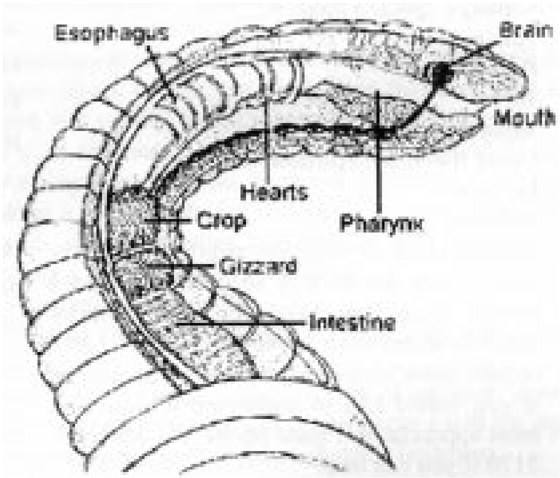
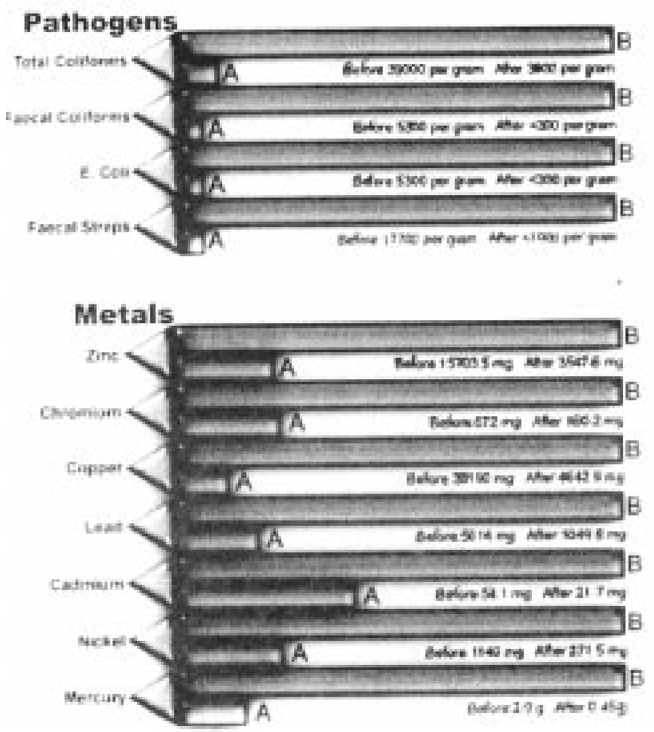


Figure 1: Earthworm intestinal tract and the production of Vermihumus: The earthworm eats food (soil aggregates — predigested organic matter, minerals and microbes) through its mouth. It is swallowed by the sucking action of the muscular pharynx, and then passes through the oesophagus (where calcium carbonate is secreted from glands to neutralize any acids in the food). The oesophagus leads into a large, thin walled sac, the crop (here microbial fermentation occurs and enzymes begin digestion), which serves only for temporary storage. Behind the crop is another sac, the gizzard (which has heavy muscular walls that grind the food thoroughly using mineral rock dust). From the gizzard the food passes through the long intestine (where the bulk of digestion and nutrient absorption occurs). The resulting nitrogen laden, highly concentrated and nutrient-rich vermihumus is then excreted from the anus.



Levels in untreated sewage:
B: at the start of the test
A: levels in casts after worms had processed the waste for 10 days.
Zoology Dept, Cork University

exceptionally unique ability to deal with pathogenic bacteria and to scavenge toxic substances and heavy metals from the soil in highly contaminated sites (10 to 24).

It's a MICROBE WORLD - Beneficial Microbes should be everywhere

Healthy soil is living soil. It is full of microorganisms that constantly break down plant material, making elemental nutrients bio-available to the plants. It is also full of earthworms — but earthworms do not have teeth. They have set up a symbiotic / mutualistic relationship with the beneficial microbes. These microbes are the worms' 'teeth'. The microbes and earthworms digest waste material, turning it into rich fertilizer, which among other things assists in the formation of soil aggregates and excellent soil structure.

However, microbes have had a very bad press over the last 120-plus years. In 1878, Louis Pasteur presented his "Germ Theory and Its Applications to Medicine and Surgery" in which

he intuited that germs were the cause of contagious diseases - i.e. pathogens. His work became the foundation for the science of microbiology, and a cornerstone of modern medicine. Ever since then, bacteria have been number one on the hit (seek and destroy) list. However, the bulk of bacteria (and other microbes such as fungi) are beneficial. The use of chemicals and antibiotics to kill the pathogens, invariably also kills the good guys as well, leading to a disproportionate overgrowth of the wrong types of microbes! In the ground, this can lead to less fertile and / or dead soil systems.

Beneficial microorganisms form a vital part in the world's cyclic food chain. They break up and decompose waste material in the human system, just as they do within the plant and animal kingdoms. When organic matter dies and decomposes, bacteria and moulds metabolize the highly complex organic molecules into simple inorganic bio-available wastes. Elements of inorganic wastes are then excreted back into the soil to be absorbed and utilized once again as food by earthworms and plants.

Some bacterial species release nitrogen, sulphur, phosphorus, and trace elements from organic matter. Others break down soil minerals and release potassium, phosphorus, magnesium, calcium and iron. Still other species make and release natural plant growth hormones, which stimulate root growth. A few species of bacteria fix nitrogen in the roots of legumes while others fix nitrogen independently of plant association.

Bacteria are responsible for converting nitrogen from ammonium to nitrate and back again depending on certain soil conditions. Other benefits to plants provided by various species of bacteria include increasing the solubility of nutrients, improving soil structure, fighting root diseases, and detoxifying soil.

Synthetic chemical fertilizers do little to build soil fertility. Synthetic fertilizers are "junk food" for plants. They simply provide plants with an instant fix of growth elements, then drain into and accumulate in the ground water and rivers — leading to over-nutrification and subsequent algal blooms etc.

In fact, many chemical fertilizers kill the microorganisms and earthworms that keep soil productive and healthy. Most beneficial microbes and earthworms are also very susceptible to concentrated toxic chemicals (most pesticides, insecticides, fungicides and herbicides) (22).

Although plants essentially require nitrogen, potassium, and phosphorous (NPK), they also require many other trace nutrients, minerals, hormones, etc, available only in healthy soils full of beneficial microbes. The goal is to restore and / or maintain healthy soil - to provide plants with all the nutrients and growth factors required to be healthy. Many believe that by adding inorganic fertilizers (NPK) to their soils they are "feeding their plants".

In reality, if there are quantities of organic matter in the soil, approximately 80-90% of the inorganic fertilizers are taken up into the life cycles of certain opportunistic microorganisms — this can lead to an overgrowth of these microorganisms; to the detriment of other beneficial soil microbes. Eventually, these opportunistic microorganisms die and then the inorganic nutrients are released into the soil in a bio-available form to be taken up by plant roots.

Soil Probiotics and Restorers

Recent developments in microbiology have identified a range of highly advanced soil microbes, which appear to have enormous problem-solving potential for agriculture. The bacteria and fungi involved are sourced from the same 'master species' which comprise part of a new 'Soil Probiotic' microbe blend, 'Biomex', that has produced dramatic results.

The product has the greatest impact where the living soil has been heavily worked and mechanically over-tilled and has become unbalanced, and organic carbon levels have plummeted. To date, toxic chemicals have provided dubious results; whereas the promise of this hardy breed of Probiotic 'pro-life' bugs is exciting: (Antibiotics = anti-life).

The Soil Probiotic is a microbial soil inoculum that contains a scientifically balanced blend of beneficial bacterial and fungal organisms totalling 23 types and strains (including *Azotobacter, Azosporillium, Bacilli, Cellulosic fungi, Phosphobacter, Pseudomonas, Rhizobium, Streptomyces and Saccharomyces).* Its use greatly increases and stimulates the natural beneficial microorganisms, resulting in massive population increases in the soil.

It is 100% organic and 100% non-toxic, and works to reintroduce and create a healthier living environment for the normal functions of the desirable microorganisms and earthworms, thus enhancing biological and sustainable life in the soil.

Whilst the primary purpose of Biomex is to balance microbial activity, many important side benefits have been noted. The product is not a fertiliser, fungicide, insecticide, herbicide or nematode control agent, however users have consistently reported the following benefits:

a. Regulation of the pH level.
b. Assists in the control of aggressive nematodes.
c. Assists in the control of pathogenic fungi.
d. Plant strength increases natural insect resistance.
e. Some insect pests are destroyed in the soil, notably lawn grubs (bacteria break down the waxy coating of their eggs).
f. Reduction in water requirements.
g. Increased root formation.
h. Increased root quality.
i. Root strength activates natural weed repulsion.
j. Increased soil mineral availability (50 to 200%).
k. Dramatic reduction in chemicals and fertilisers required.
1. Rapid breakdown of added organic matter.
m. Increased protein level of crops.
n. Improved fibre/moisture ratio aids frost resistance.
o. Better appearance.
p. Improved soil and plant life quality.
q. Improved soil workability. Better soil moisture retention.
r. Soil improvement resists water and wind erosion.

s. Improved frost and drought resistance.
t. Increased nutrient level of crops.
u. Increased earthworm activity.

Conclusion

In conclusion, earthworms and beneficial microbes are the superheroes of the soil. They mobilize essential minerals and create and maintain excellent soil structure and humus content — all contributing to a balanced healthy micro-environment, and an ecologically sustainable soil system.

References

(1) **Hubbard** VC, Jordan D, Stecker JA. *Earthworm response to rotation and tillage in a Missouri clay pan soil*. Biol Fert Soils 1999, 29(4), 343-347.

(2) **Aslam** T, Choudhary MA, Saggar S. *Tillage impacts on soil microbial biomass C, N and P, earthworms and agronomy after two years of cropping following permanent pasture in New Zealand*. Soil Till Res 1999, 51(1-2), 103-111.

(3) **VandenBygaart** AJ, Protz R, Tomlin AD, Miller JJ. *Tillage system effects on near-surface soil morphology: observations from the landscape to micro-scale in silt loam soils of southwestern Ontario*. Soil Till Res 1999, 51(1-2), 139-149.

(4) **Byron** J. *Pesticide mixtures more lethal to earthworms, study finds*. Environ Sci Technol 1999, 33 (11), 229A.

(5) **Wagman** N, Strandberg B, vanBavel B, Bergqvist PA, Oberg L, Rappe C. *Organochlorine pesticides and polychlorinated biphenyls in household composts and earthworms (Eisenia foetida)*. Environ Toxicol Chem 1999, 18(6), 1157- 1163.

(6) **Krogmann** U, Boyles LS, Bamka WJ, Chaiprapat S, Martel CJ . *Biosolids and sludge management*. Water Environ Res 1999, 71 (5), 692-714.

(7) **Zaller** JG, Arnone JA, 111. *Interactions between plant species and earthworm casts in a calcareous grassland under elevated CO_2*. Ecology 1999, 80(3), 873-881.

(8) **Mele** PM, Carter MR. *Species abundance of earthworms in arable and pasture soils in south-eastern Australia*. Appl Soil Ecol 1999, 12(2), 129-137.

(9) **Kaushal** BR, Bora S, Kandpal B. *Growth and cocoon production by the earthworm Metaphire houletti (Oligochaeta) in different food sources*. Biol Fert Soils 1999, 29(4), 394-400.

(10) **Ciavatta** C, Figliolia A, Leita L, Petruzzelli G. *Evaluation of heavy metals during stabilization of organic matter in compost produced with municipal solid wastes (MSW): Chemical, agronomical and environmental aspects*. In: Cheremisinoff PN, ed. Ecological Issues and Environmental Impact Assessment. Houston: Gulf Publ Co, 1997: 613-631.

(11) **Elizabeth** Gibson et al *'National framework for ecological risk assessment of contaminated sites'*; Victorian Environment Protection Authority for Environment Australia, April, 1997.

(12) **Marino** F, Morgan AJ. *The time-course of metal (Ca, Cd, Cu, Pb, Zn) accumulation from a contaminated soil by three populations of the earthworm, Lumbricus rubellus*. Appl Soil Ecol 1999, 12(2), 169 177.
(13) **Marino** F, Morgan AJ. *Equilibrated body metal concentrations in laboratory-exposed earthworms: can they be used to screen candidate metal-adapted populations?* Appl Soil Ecol 1999, 12(2), 179189.
(14) **Panda** R, Pati SS, Sahu SK. *Accumulation of zinc and its effects on the growth, reproduction and life cycle of Drawida willsi (Oligochaeta), a dominant earthworm in Indian crop fields*. Biol Fert Soils 1999, 29(4), 419-423.
(15) **Kirbas** Z, Keskin N, Guner A. *Biodegradation of polyvinyl chloride (PVC) by white rot fungi*. Bull Environ Contam Toxicol 1999, 63(3), 335-342.
(16) **Ramos** L, Fernandez MA, Gonzalez MJ, Hernandez LM. *Heavy metal pollution in water, sediments, and earthworms from the Ehro River, Spain*. Bull Environ Contam Toxicol 1999, 63(3), 305-311.
(17) **Schrock** ME, Barrows ES, Rosman LB . *Biota-to-sediment accumulation factors for TCDD and TCDF in worms from 28-day bioaccumulation tests.* Chemosphere 1997, 34(5-7), 1333- 1339.
(18) **Schreiner** G, Wiedmann T, Schimmel H, Ballschmiter K. *Influence of the substitution pattern on the microbial degradation of mono- to tetra-chlorinated dibenzo-p-dioxins and dibenzofurans.* Chemosphere 1997,34 (5-7), 1315-1331.

[Based on an article in Permaculture West [Journal of the Permaculture Association of Western Australia, Vol 23. No. 2, March 2001]

Permaculture Association of Western Australia: A1441.