Organic Farming in the
Tropics and Subtropics

Exemplary Description of 20 Crops

Macadamia Nuts

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Franz Augstburger, Jörn Berger, Udo Censkowsky,
Petra Heid, Joachim Milz, Christine Streit.

The cultivation guidelines are available in English, Spanish and German for the following crops:
banana, brazil nut, cashew nut, cocoa, coconut, coffee,
cotton, hibiscus, macadamia, mango, papaya, peanut,
pepper, pineapple, sugar cane, sesame, tea, vanilla.

The cultivation guidelines for Bananas, Mangoes, Pineapples and Pepper were revised in 2001 for the United Nations Conference on Trade and Development (UNCTAD) by Udo Censkowsky and Friederike Höngen.

In 2002 two more guidelines, for rice and date palms, were published in English.

All the authors emphasize, that the cultivation recommendations at hand can just provide general information. They do not substitute technical assistance to the farmers with regard to the location.

All indications, data and results of this cultivation guidelines have been compiled and cross-checked most carefully by the authors. Yet mistakes with regard to the contents cannot be precluded. The indicated legal regulations are based on the state of the year 1999 and are subject to alterations in future. Consequently all information has to be given in exclusion of any obligation or guarantee by Naturland e.V. or the authors. Both Naturland e.V. and authors therefore do not accept any responsibility or liability.

Furthermore the authors kindly call upon for critical remarks, additions and other important information to be forwarded to the address below. The cultivation guidelines will be updated regularly by Naturland e.V.

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Organic Cultivation of Macadamia Nuts

1. Introduction

Up to now, the macadamia is the only commercially cultivated food crop that originates from Australia. The natural habitat of this nut tree is in the subtropical rainforests on the Australian East coast in Queensland and New South Wales. The macadamia was always an important source of food for the Aborigines. Commercial cultivation of the nut began in the 30‘s on Hawaii, was taken up in Australia during the 60’s and then spread rapidly across the North American continent. The world-wide increase in its familiarity and popularity has led to demand continually outstripping supply of the “gourmet nut”, and thus secured constant high prices to this day. During the last few years, huge areas have been planted which will begin producing around the turn of the century – thus leading to a reduction in price[1].

1.1. Botany

The macadamia belongs to the family of proteaceae, which consists of evergreen woody plants. The trees grow to a height of around 15-20 m. The bunch-like flower clusters grow to 30 cm long with 100-300 blossoms. The blossoms of *macadamia integrifolia* are yellow-white, and those of *macadamia tetraphylla* pink. They are hermaphrodites, and are capable of self-fertilisation. Nevertheless, the plants are often self-sterile, and therefore, almost every plantation will cultivate different varieties in order to encourage allogamy[2].It takes around 6-11 months from the blossom to ripened nuts.

1.2. Varieties and countries of origin

Two different varieties and their hybrids are of importance in commercial cultivation:
Macadamia integrifolia (also M. ternifolia) and *macadamia tetraphylla*.
M. tetraphylla is most suited to cooler locations. It originates in Australia between the southern latitudes 27° and 29°. *M. integrifolia* comes from southern latitude 23°-27°, and is better suited to warmer, dryer locations.

[1] TREEGART, B. (1994): The macadamia - A Native Australian Gourmet Nut. Diplomarbeit Witzenhausen.

[2] Honey and wild bees are excellent pollinators, whereas the wind barely plays a role in pollination.

Different characteristics				
M. integrifolia	3 leaves per leaf whorl	White blossoms	Leaves hardly spiked	Smooth-shelled
M. tetrapylla	4 leaves per leaf whorl	Pink blossoms	Leaves mostly spiked	Rough-shelled

To this day, more *M. integrifolia*-varieties have been planted because cross-breeding cultivation of the macadamia began on Hawaii, where *M. tetraphylla* is not so well-adapted to the climate. The crop then spread from Hawaii into other countries. For this reason, there are many adapted varieties of *M. integrifolia*- varieties at different sites.

Organic cultivation has only really just begun on a small scale in Australia and New Zealand; in Kenya, large areas are being converted[3]. High-yield varieties can cause problems on organic cultivations, because they require a larger amount of nutrients, and are more susceptible to drought, diseases and pests[4]. When selecting a variety for planting, it is essential to have accurate knowledge of the site's weather conditions.

1.3. Uses and contents

Due to their fine aroma, macadamia is counted as one of the most exquisite edible nuts. Light roasting with or without coconut oil and salt can increase the aroma.

Types of uses for macadamia:

- In the form of raw or roasted, whole or chopped nuts.
- The raw nuts are processed into confectionery, bakery products, nut paste,
- sauces and ice-cream.
- Nuts of a lower quality are used to make edible oils, soaps and cosmetics.
- The press-cakes can be used as a substitute for fodder.
- The pericarp (husk) is composted for 1 year before being spread over the crops as fertiliser (or used as potting soil).
- The husk is useful as a fuel, and is often used to dry the nuts, as well as for roasting coffee and manufacturing coke.
- The hard wood is mostly used by carpenters.

[3] Gesellschaft für Ressourcenschutz GmbH (1998): Verbal note. Göttingen.

[4] TREEGART, B. (1998): Verbal note. Hannover.

Pericarp, husk and kernel as constituents of M. integrifolia in % of dry weight[5]

Contents	Pericarp	Husk	Nut
Tannin	4.5	--	--
Water	17.7	10.39-19.98	2.92-5.1
Ash	3.7	0.86-2.3	1.43-1.88
N	0.6	0.26-0.28	1.14-1.16
P	0.07	0.02-0.03	0.18-0.21
K	1.85	0.09-0.17	0.21-0.66
Ca	0.12	0.08-0.1	0.08-0.31
Mg	0.12	0.01-0.04	0.11-0.13
Sugar	--	--	3.68-6.51
Carbohydrates (total)	--	21.04-23.75	9-14.81
Starch	--	--	--
Fat	--	0.28-0.32	71.4-75.44
Raw fibres	--	61.15-65.75	1-2.3

2. Aspects of plant cultivation

2.1. Site requirements

There are only a few wooded areas of the macadamia's original habitat, the pretty dry Australian rainforest, which have retained their natural state. By reaching up directly towards the light in a dense forest, macadamia can attain a height of 20 m (on plantations, 6-8 m) and belongs within the medium upper reaches of the forest. The trees which tower over macadamia are deciduous, and therefore have no leaves for 6 months of the year. This means that during this time the macadamia can grow in the direct sunlight. This characteristic in its natural habitat can provide hints at how to integrate macadamia into an agro forestry systems. Macadamia grow well on basalt and granite ground, which are porous and well-weathered. The tree will not grow on neighbouring sandy or slate, or on rhyolite and trachyte grounds, despite them receiving the same amount of rainfall. After rainforests bush-land have been eroded, macadamia can be found – having apparently self-pollinated – along the banks of rivers[6].

[5] KERMONT, P. and TREEGART, B. (1995): The macadamia: from the seed to the supermarket. Australia.
[6] TREEGART, B. (1994): The macadamia - A Native Australian Gourmet Nut. Thesis Witzenhausen.

Its hard foliage and proteoid-roots enable the macadamia tree to adapt itself to harsh Mediterranean climates, yet for decent yields, the conditions required are more highly defined then those required merely for growth. The most suitable is a warm, semi-humid, subtropical climate.

2.1.1. Climatic requirements

Temperature

Temperature (especially the average daily and seasonal range of temperature) plays an essential role in the size of yield[7].

Macadamia trees provide good yields in areas with:

- Yearly average temperatures around 20-25°C.
- The difference between the average daily and nightly temperatures should be at least 8°C.
- Average summer temperatures around 25-30°C.
- Average winter temperatures around 20°C.
- In order for blossoming to commence, the nightly temperatures must fall below 19°C.
- Frost-free regions are recommended. Frost below -6°C will kill off young trees and destroy the leaves and blossoms of older trees. Light frost can be withstood by older trees; sensitivity to frost is very similar to avocado, lemons and oranges. Below 10°C, the content and composition of fatty acids is impaired.
- During long periods above 40°C, those leaves exposed to solar radiation will burn, and the yield will be diminished.

Altitudes

Good sites are in subtropical regions with continental climates. They can also be found, though, in special micro climates, such as e.g. on Hawaii. There, the quality of the kernels decreases below 700 m.. This has little to do directly with altitude, though, but more to do with the increase in humidity and cooler temperatures caused by a constantly rising mist. In South East Asia, near to the equator, the trees grow well, yet only blossom and carry fruit sporadically throughout the year – which is due to a lack of seasonal temperature differences. In Kenya (also on the equator), successful plantations are located between 1000 and 1900 m with clear-cut seasonal climates. There, the growing and blossoming phases are synchronised after a cool, cloudy season. The main season provides plenty of sunshine again[8].

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[7] STEPHENSON, R. A. and WINKS, C. W. (1991): macadamia integrifolia. In PROSEA Plant resources of South- East Asia, -2- fruits and edible nuts. Verheij E.W.M. and Coronel R.E. (Hrsg.) Pudoc/Prosea Wageningen.

[8] STEPHENSON, R.A. and WINKS, C.W. (1991): macadamia integrifolia. In PROSEA Plant resources of South- East Asia, -2- fruits and edible nuts. Verheij E.W.M. and Coronel R.E. (Hrsg.) Pudoc/Prosea Wageningen.

Water requirements

- An average rainfall of 1500-2500 mm is sufficient at most sites.
- On porous, volcanic rock – such as on Hawaii – macadamia can also thrive with rainfalls of over 4000 mm.
- The relatively flat root system means that rainfall needs to be spread throughout the year.
- Periods of the highest demand of water are during nut formation and oil accumulation (in Australia from November until January).
- If sufficient rainfall is available, irrigation will not serve to increase the yield, yet under 1000 mm rainfall, it can make all the difference.

Humidity

Muggy conditions will increase susceptibility to Raceme Blight *(Botrytis cinerea)*, nut anthracnose *(Colletotrichum gleosporiodes* var. *Minor*) and Husk spot *(Cercospora*); misty sites should therefore be avoided, whilst enough air must circulate through the system.

Wind

- Very strong winds will break branches and uproot trees. Wind-sensitive varieties include: 800, 246, 508. Wind-resistant varieties include: 344, 660, 741, A4, A16.
- Strong wind reduces growth, blossoms and yield.

2.1.2. Soil requirements

A variety of soils are suitable for cultivation, providing they are well-drained and have a pH-value of 5.0-6.5 (optimum 5.0-5.5). Loose, deep loam is ideal, yet due to its adaptability, many soils that are well-supplied with humus and a medium amount of nutrients are suitable for macadamia. Heavy, impermeable clay soils, as well as badly structured soils should be avoided, because the flat system of roots needs well-drained soil in order to minimise the risk of getting trunk canker *Phytophtora* - plant growth on such soils is also hindered, and the fruits may be aborted.

2.2. Seeds

Propagation on commercial plantations is always by vegetative method, as otherwise, the variety-characteristics become lost. Reducing the risk of passing over diseases is the number one priority in tree nurseries. Seedlings function as stocks, which are sown in beds made of coarse river sand with the join facing downwards (minimum distance of 3 cm).

In Australia, seedlings of the variety H2 are preferred as stocks; 741 and *M. tetraphylla* are also used. Nuts to be used as seeds can be stored for at least 1

season. Germination of most of the nuts takes 3-5 weeks. As soon as the seedlings are 5 cm tall, and have 2-3 green leaves (they are pink at first), they are transplanted into large, sturdy plastic bags. Only plants with well-developed root systems should be chosen. The 9-12 month old seedlings, which have a diameter of 1-1.3 cm, can now be used as root stocks.

The scions are ringed 6-8 before they are grafted, by removing a 2.5 cm wide ring from the bark and cambium zone, in order to introduce more carbohydrates into the scion . The most advantageous times to graft are autumn, and especially in the spring. The most successful methods are "whip-grafting" and budding. Macadamia is difficult to graft due to its hard wood; it is important to use sharp, disinfected instruments, and scions and stocks of similar diameters.

Young plants grow most rapidly after they have developed proteoid-roots. Some macadamia grafters choose to add soil taken from older, well-established cultures to the propagating medium[9]. This results in a significant improvement in growth (reasons for this have yet to be explained). Small, regular additions of leaf fertiliser are useful to the tree nursery. The trees are transplanted into the plantation only after they have attained 40 cm in height, and must be well-used to the sun by then. By grafting, the period from planting until the first fruit can be harvested is shortened from 7 to 3 years.

2.3. Planting methods

When considering cultivation of a large area, the advice of experts should be sought, as mistakes take a long time to notice, and are usually irreversible.

Protection against wind, alignment of the rows, drainage and irrigation etc. must all be planned from the beginning. Protection against wind needs to be well-established on the plantation; *Casuarina,* a rapidly-growing legume tree, offers good results.

Recommendations for the distances between plants are difficult to generalise, because they depend on several factors, such as e.g. variety (upright or bushy form), site topography, soil fertility, rainfall (irrigation possibilities), wind protection measures and mechanisation. As a rule of thumb:

Distance between rows: 7-11 m

Distance within rows: 4-8 m.

Dense crop leads to a high yield/ha during the first 10 years; but also entails higher plant and trimming costs. It is usual to plant trees densely on a system, and then to erode up to half of the crop as the yield decreases due to a light deficit. Suitable varieties: 660, 344, A16, 741.

Looser crop entails less costs, and a longer period before radical trimming is required.

[9] MALCOLM, H., and TROCHOULIAS, T. (1979): Proteoid roots help macadamia nut trees. Agricultural Gazette of New South Wales 90 (1), Australia.

Suitable varieties: 246, 800, 333.
The yield per surface area is identical in both systems as soon as the crop has covered the terrain.

Planting is carried out in spring or autumn at mild temperatures or the start of the rainy season. The young plants need to be around 40 cm tall; although larger examples are hardier, when they grow for too long in plastic bags, their root systems become deformed that reduces the rate of growth. The root system should be checked again, and only well-developed plants transferred to the site. Root growth can be encouraged by lightly pruning them.
The planting hole should be 45 cm deep and 60 cm in diameter. When filling the hole, it is recommended to mix some compost and rock phosphate together with the dark top soil, The plant should then be pressed down with a heel and watered immediately, to provide root contact with the soil. Some fresh animal or chicken manure can be worked into the surface before mulch is added. If they are not attached to a stake, the trees should be planted at an angle of 10° to the wind direction, when will develop strong trunks.
Mulch is added to protect against weed growth and drying out, at first in a radius of 1 m, then later to the diameter of the crown. The material should be spread in layers around 5-10 cm deep, and not touch the trunk. In hot regions with temperatures over 30-35°C rapidly growing trees should be planted to provide shading for the crop in its early stages of development.

2.4. Diversification strategies

Conventional production of macadamia is carried out mainly on large plantations. These sites have been adapted to maximise mechanisation and yield, and experience problems when being converted to organic cultivation. In less-industrialised countries, the intensive use of machines is usually not worth it. Use of manual labour allows the plantation to be run more flexibly, and better adapted to the site conditions, as no allowance need to be made access by machines. The rows can then be planted along the contour lines, whilst manual harvesting allows thicker mulching layers to be applied.
Macadamia is well-suite to cultivation on agro forestry systems. Several plantations in Africa (Kenya, Tanzania, Malawi) have been successful by also cultivating coffee in multi-layer systems,[10] as well as in central and Latin America (Columbia, Guatemala, Bolivia). The local conditions need to be considered when setting the distances between the plants, so that fungi infestations are not stimulated by too wet conditions in the crop.
In New Zealand and Australia, plantations have been established in combination with forest trees. The combination of macadamia with *Paulownia* has produced good

[10] WAITHAKA, J. H. G. (1998): Written information. Agricultural Extension Office. Nairobi.

results; certain eucalyptus varieties are aggressively competitive towards macadamia[11].
During the first few years, annual crops can be planted between the macadamia-rows, such as manioc, maize, beans, vegetables and herbs[12]. If this is to be carried on after the first 10 years, then the distances between the macadamia-rows must be accordingly large. Perennial crops are also suitable, such as pineapples, bananas, coffee, maracuja, papaya and avocado (the latter should not overshadow the macadamia, though).
In agro forestry systems, care must be taken that the varieties of tree that are to provide shade for the macadamia are deciduous. Non-deciduous trees will need to be cut back before the blossom and fruiting periods, to provide enough light. Principally, as many of the local varieties as possible should be integrated into the cultivation system.

2.5. Nutrients and organic fertilisation management

As with many of the hard leaf species, macadamia forms proteoid-roots, which lend it an efficient system of nutrient gathering in poor soils. When few nutrients are available, more proteoid-roots are formed, which secrete organic acids from the large surfaces of their root bunches, thereby making nutrients available – especially phosphate, which is otherwise difficult to dissolve.
During the first 4 years, animal manure (if available) and thick mulch can be used throughout the whole year. Later on, care must be taken that not too much animal fertiliser is applied, causing an excess of nitrogen and deficiency of potassium, and the pH-value to rise sharply. In the case of organic fertiliser with a strong nitrogen content, such as fresh dung, the yearly cycle of the trees must be considered, so that a rise in growth is not stimulated during the nut formation phase. Soft leaves and fewer proteoid roots are caused by soil which contains too many nutrients.
Good results have been gained from using fertiliser with basalt meal (includes a high potassium content). The best type is basalt meal from quarries which has a kernel size of < 2-5 mm[13].

Examples of fertilisers used:

- Rock-meal
- Compost
- Dung
- Sowing with ground-covering green fertiliser plants
- Mulch
- Algae fertiliser (rich in trace elements)

[11] KERMONT, P. (1998): Written information. Macadamia cultivation and consultancy. Queensland.
[12] WAITHAKA, J. H. G. (1998): Written information. Nairobi.
[13] BOBBERT, H. (1998): Verbald information. Biodynamic macadamia cultivation. Australia.

Nutrient extraction of 1000 kg "Nuts in Husk"[14]

Plant part	**N** [kg]	**P** [kg]	**K** [kg]	**Ca** [kg]
pericarp (husks)	21.2	1.1	28.0	1.0
Shell	7.3	1.4	2.9	0.7
nuts	12.0	1.2	2.4	0.4
Total	**40.5**	**3.7**	**33.3**	**2.1**

Mulch

Macadamia trees are specialised in extracting nutrients directly from decomposing organic substances within soils of low fertility.

The various **advantages** of a layer of mulch are:

- Protection of the root system against temperature extremes
- Stimulation of soil fauna
- An increase in the water-retaining capacity of the soil, and thereby, protection against evaporation
- Avoidance of the soil becoming muddy
- Growth stimulation for the proteoid-roots
- Control of weed growth (comp. 2.7.3.)
- Increases the ratio of organic material in the soil, which also offers an overall increase in the soil's fertility

Suitable mulch include, e.g. grass and covering plant prunings, material stemming from tree trimmings, well-composted pericarp, barnergrass, sugar cane bagasse, legume foliage, maize and sorgo stalks, peanut shells and dung.

2.6. Biological methods of plant protection

2.6.1. Diseases

In relation to other types of trees, macadamia is affected by only few serious diseases. Viruses play no role, and bacteria only a small one. The choice of the cultivation site plays a large part in preventing an infestation by fungi.

[14] KERMONT, P. and TREEGART, B. (1995): The macadamia: from the seed to the supermarket. Australia.

Important diseases on macadamia plantations include:

Fungi	Preventative and combative measures
Phytophtora cinamoni Trunk canker	Also affects avocado and pineapples. Problematic, especially in tree nurseries and for young trees. Only plant healthy trees. Avoid soil compression, water-logging, damage to trunks and spraying sludge. Remove bark and apply Bordeaux-paste[15].
Armillaria mellea, Root rot	Common on freshly eroded land, infection from tree roots. Tear out infected trees in time, and disinfect soil against further outbreaks with quicklime.
Pseudocercospora sp. macadamia husk spot	Only in Australia. Heavy loss of nuts. Finish harvest before blossom begins. Finger- weel- harvester give off less spores. Plant resistant varieties.
Ceratocystis fimbriata	If soil water-logged, cool climate and bark damaged.
Rosellinia bunodos	Preventative ground liming. Remove infected trees.
Botrydiplodia theobromae	Hygienic conditions during grafting.
Phytophtora palmivora	Distance to cacao and rubber plantations. Too high relative humidity.

2.6.2. Pests

Biological pest control is not only of interest for organic cultivation, but also in IPM (Integrated Pest Management). The current state of research should be pursued further. On widely diversified plantations (agroforestry systems), hardly any pests infestations occur.

[15] According to the European Regulation for Organic Agriculture (EEC) 2092/91 the use of copper preparations for plant protection (e.g. Bordeaux Mixture) is allowed for a transitional period which will end at the 31st of March 2002. However, any use of copper preparations until 2002 has to be approved by the certification body. In case copper preparations have to be applied it is recommended to use preparations which contain less copper and therefore to reduce the accumulation of copper in soils (e.g. tribasic copper sulphate, copper hydroxide).

The following insects can become pests on macadamia plantations:

Insect	Peculiarities
Flower caterpillar *Homoeosoma vagella*	More infestations in warmer regions. Collect together in time. A variety of parasites exist e.g. *Trichogramma*, therefore, avoid such broad effect preparations as neem[16]. In emergency: *Bacillus thuringiensis.*
Fruit spotting bug *Amblypelta nitida*	Host plants: Avocado, Mango, Cashew, Papaya, Guava, Lemon. Egg parasites and pheromone traps are being tested in Australia.
Macadamia nut borer *Cryptophlebia ombrodelta*	Larvae eat nuts. Host plants: Lychees, Pecan, Maracuya and ornamental plants. (Poincianas and Bauhinias). *Trichogramma cryptophlebia* have been successfully used in South Africa. *Elachertus sp*. used in China and pheromone traps are being developed in Australia.
Macadamia felted coccid *Eriococcus ironsidei*	Caution in tree nurseries: Infection through scion transport and shipping onto new, healthy plantations must be avoided at all costs.
Macadamia twig- girdler *Neodrepta luteotactella*	There are 20 different insects, therefore, do not use broad effect preparations, but instead, parasites.
Macadamia leafminer *Acrocercops chionosema*	Mostly on young leaves (tree nurseries), less trimming will prevent growth in phases. *Elachertus sp*. have been used successfully.
Green vegetable bug *Nezara viridula*	Also on pecan nuts. Tests in Australia with aggressive flies have not yet been completed.

Rats and other rodents will readily eat the nuts, and can cause considerable losses, whereby it is also the case here that diverse cultivation systems can significantly reduce the amount of damage caused.

Recommended measures include[17]:

- Harvesting often and regularly.
- Remove all of the nuts during the last harvest.

[16] According to the European Regulation for Organic Agriculture (EEC) 2092/91 the application of Neem preparations is restricted and only allowed for the production of seed and seedlings. This regulation is discussed controversial. An up-date information is available from your certification body.

[17] A mixture which is useful against rats consists of:

a) Parts maize flour, 1 part cement and 1 part grated cheese

b) Parts wholewheat, 1 part plaster of Paris and 1 part grated cheese Place a bowl of water next to it. Be careful to keep out of childrens' reach! (SCHULZ, B. (1993) Ökologischer Landbau im Südosten Brasiliens. Der Tropenlandwirt (51), Witzenhausen.). The learning capabilities of rats are such that they will avoid a quick-acting bait as soon as the first rat has died of it (BROSZAT, W. (1995) Macadamia-Nüsse anbauen. Deutscher Entwicklungs Dienst, Germany).

- Keep cats as pets.
- Cut the barner-grass wind protection as soon as the trees begin to bear fruit.
- Remove rat nests.
- Lemon verbena *(Aloysia triphylla)* used as a bait will cause lethal high blood pressure in rats.

2.7. Crop monitoring and maintenance

2.7.1. Pruning

Young trees:
Vegetative growth should be stimulated during the first 4 years after planting. The leading shoot should be fostered during the first 2 years, and the later risk of branches breaking minimised, especially in the case of wide-spreading varieties, through pruning measures. Upright growing varieties such as the Kau (344) and Mauka (741) require less pruning as they are more resistant against the wind. No more than 10% should be removed during each trim in order not to inhibit growth. At a height of 80 cm, the leading shoot is clipped to stimulate branching. At a later date, cleft branches are removed from the upper branches[18]. Only two branches are left at each knot, and the next 1-2 branches 1.5-2 m higher up, pointing in a different direction to those below. Stolons should be regularly removed.

Trees bearing fruit:
Maintenance work begins in spring, directly following the last harvest. On larger trees, branches which are too old, unproductive, broken, dried out, diseased and those growing inwards are cut away, and any nuts left hanging removed. As the plantation grows older, the standing crop will become denser, and needs to be pruned regularly. The resulting material should be finely chopped into mulch and spread evenly over the ground. If necessary, the soil between the rows can be loosened to facilitate drainage. Drains that have become blocked with soil and organic material must be cleared; puddles and rat holes beneath the trees filled in.
Directly before the next harvest begins, the soil needs to be cleared. The harvesting machines currently in use require much cleaner soil than manual harvesting – blowers, special windrowers and mulching machines are utilised. Before manual harvesting commences, only the grass needs to be mowed, and the fallen nuts collected and disposed of – most of them will be unripe and infected with insects.

[18] Cleft branches have an acute angle, and a fold in the bark of the fork; they tend to break under pressure.

2.7.3. Weeding

Mulch

The best way to avoid weed-growth is to apply a thick layer of mulch (10-15 cm). Care must be taken to avoid it touching the trunks to prevent them rotting. Mulch is best applied after the harvest has been completed to allow the material plenty of time to decompose before the next fruits are formed.

Covering crop

Growth between the rows is advantageous (to protect the roots, nitrogen fixing, protection against erosion and evaporation, and as fodder). Yet concomitant vegetation may also compete with the trees for water and nutrients. Simultaneously, growth under the tree crowns can be of hindrance during both mechanical and manual harvesting. Both aspects must be considered when choosing the type of soil coverers. Deep-rooted varieties are preferable because macadamia itself produces flat root systems. An additional weeding will be necessary at first, until the soil is properly covered.

Suitable soil coverers include:

- Shade, drought and if necessary frost resistant,
- non-climbing,
- perennial,
- easy-to-care-for,
- No hosts for macadamia pests.

Arachis pintoi is a good, perennial soil coverer, tolerant of shade, yet it will attract rats lured to the peanuts it produces. *Lotus pendunculatus* (Maku Lotus) has shown good results in tests, although it takes two years to establish. It also needs to be mown before harvesting due to its upright growth. Other suitable legumes include lucerne, lupines, *Crotalaria spp*. and *Desmodium spp*. An inoculation of legume seeds with the appropriate rhizobium is recommended, to ensure rapid nodulation and nitrogen fixation.

2.8. Harvesting and post harvest treatment

The first economical harvest can be expected around 7 years after planting. The maximum yield will be achieved after around 15-20 years. The average yield in Australia is 5.5 t, in Hawaii 7.5 t of nuts in their shells/ha. Depending on the crop density and site, this amounts to between 20 and 45 kg per tree.

2.8.1. Harvesting

Because the ripeness of the nuts is difficult to gauge optically, the fruit is not generally picked from the tree. It is better to wait until the ripe nuts have fallen, and then to

regularly collect them, either mechanically or by hand. Short harvesting intervals of 1-2 weeks will reduce losses caused by rats and decay. The harvesting period last between 3-6 months, depending on the variety and climate.
One disadvantage of harvesting machines used up to date, is that they can only function correctly on cleared ground. At the same time, they also damage the fibrous roots that suffer from the soil compression caused by it being driven on by heavy equipment. Mechanical harvesting is only worthwhile under Australian conditions above a yield of a 35 t annual harvest (Nut in shell) and only works well on flat to undulating ground; long rows are a necessity.
Advantages of manual harvesting: The valuable layer of mulch and the surface root systems are neither damaged nor removed. Stones are not included in the harvest. Harvesting is also possible on wet soil, and in areas inaccessible to machines. Nets strung out under the trees can facilitate manual harvesting, as the nuts will fall into them – thereby also rendering a preliminary clearing of the ground unnecessary. Another advantage of using nets is that the nuts do not come into contact with the ground, thereby reducing the risk of fungus infection; the disadvantages lie in the higher investment and maintenance costs.
Advantages of mechanical harvesting: Lower costs on large plantations; avoidance of a lack of available labour. The weighing of individual harvester collections to gauge payment is unnecessary.

2.8.2. Processing on the farm

Within 24 hours, the nuts are de-husked of their green shells on the farm before they are sold, as they might otherwise warm up. If the harvest has been carried out mechanically, it first needs to be cleansed of foreign particles to avoid damaging the de-husker. Afterwards, the unshelled nuts are sorted in a water bath, where the unripe nuts float on the surface whilst the ripe ones sink.
The nuts floating on the surface must nevertheless be checked, as sometimes, ripe nuts with a low water content will float as well. The floating nuts are therefore occasionally shelled and then placed back in the water to see if they float again. If they sink, they are either unripe or damaged. Ripe, shelled nuts float due to their high oil content.
The nuts are generally stored with their shells in silos with a constant air-blower operating, and thereby dried from an original moisture content of 25% down to around 10%, or, they are shipped away immediately. Nuts from *M. tetraphylla* and *M. integrifolia* are processed separately. Nuts harvested from non-grafted trees are difficult to process due to their fluctuating quality and are therefore often consumed on the farm.

3. Product specifications

3.1. Macadamia nuts

3.1.1. Processing

Because of their fine aroma, taste and texture, macadamia nuts are counted as being among the best and finest nuts in the world, and have an appropriately high trading value. They are traded in a variety of quality grades, and further processed in the snack, confectionery, chocolate and baking industries.

The following is a description of the various stages in preparing macadamia nuts:

- **Drying**

As soon as they have been delivered to the processing plant, the nuts are dried to a moisture content of 1.5%; this is essential to facilitate breaking them open without damaging the nuts, and also prevents bits of them sticking to the inside of the shell. It is also a prerequisite for correct storage and roasting. The drying process takes between 31-270 hours, according to the temperature used.

- **Shelling**

The macadamias' extremely hard shells are usually cracked open mechanically with v-shaped, rotating rollers. Nut sizes of 12-35 mm are suitable for this. Special nutcrackers are needed when breaking them open by hand, yet even lowly hammers are sometimes also used. The nut yield lies at around 30-40%.

- **Roasting**

The most important processing stage is roasting the nuts to the desired shade:
Macadamia nuts are either roasted dry at 135°C; or in macadamia oil, partially hydrated soya oil or in coconut oil at 136°C for 12-15 minutes. One major advantage that soya oil has over coconut oil is that it does not interfere with the non-saturated fatty acids within the nut itself. Dry roasting inside stainless steel drums is only possible with *M. integrifolia*. The high sugar content of *M. tetraphylla* caramelises during roasting, and although this results in a wonderful taste, it is unwanted because of the brown discolouring it causes.

- **Cleaning and sorting**

A variety of methods are utilised to clean and sort the nuts, among them: with grain graders, blow-cleansing and electronic colour-sorting. Yet each of these methods resorts to hand-picking as the final and decisive step. The oil content of the nuts is established through floating them in water or salt-water baths, whereby they are graded into the following qualities:

Grade 1: Specific weight < 1.00 equals an oil content of > 75%.
These nuts are left whole, to be eaten.

Grade 2 : Specific weight 1.00-1.02; oil content 75% to 71%.
These nuts are usually processed into confectionery and baking products.

Lower quality: Specific weight > 1.02; oil content <71%.
The nuts are not roasted, but instead, used to manufacture oil.

Before they are packed, foreign particles are removed (stones, shell rests etc.). Macadamia nuts are sorted into the following quality classes ('styles'), which details the number of whole nuts in a unit. The diameter of the macadamia nuts in mm is used as the measuring criteria.

Style no.	Name	Description
0	Super Macs	min. 95% large whole kernels
1	Wholes	min. 90% whole kernels
2	Wholes and Halves	min. 50% whole kernels
3	Cocktail	min. 15% whole kernels and min. 90% half and larger
4	Titbits	min. 80% half kernels, max. 5% wholes (size min. 9 mm)
5	Large diced	industrial roasted product (size 9-12 mm)
6	Chips	suitable for industrial use (size min. 5 mm)
7	Bits	industrial roasted product (size 3-6 mm)
8	Fines	suitable for industrial use (size smaller than 3 mm)

Macadamia nuts are not permitted to be treated with methyl bromide or ethylene oxide, and also not irradiated with ionising rays.

3.1.2. Quality requirements

The following is a list of quality characteristics with minimum and maximum values for macadamia nuts that are usually required officially or by importers. Different minimum and maximum values can be agreed between importers and exporters, providing these do not clash with official regulations.

Quality characteristics	Minimum and maximum values
Appearance	Specific, acc. to quality
Taste and smell	Acc. to variety, fresh, not rancid, not stale
Purity	Free of foreign matter, i.e. sand, stones, shell parts, insects etc.
Peroxide value	max. 1.0 milli-equivalent of peroxide per kg fat
Free fatty acids	max. 1.0 %

Residues	
Pesticides	Not measurable
Bromide and ethylene oxide	Not measurable
Heavy metals	
Lead (Pb)	max. 0.50 mg/kg
Cadmium (Cd)	max. 0.05 mg/kg
Mercury (Hg)	max. 0.03 mg/kg
Micro-organisms	
Total number of parts	max. 10.000/g
Yeasts and fungus	max. 500/g
Enterobacteria	max. 10/g
Coliforms	max. 10/g
Escherichia coli	Not measurable
Staphylococcus aureus	max. 100/g
Salmonella	Not measurable in 25 g
Mycotoxins	
Aflatoxin B1	max. 2 µg/kg
Total aflatoxins B1, B2, G1, G2	max. 4 µg/kg

In order that the quality requirements are upheld, and no contamination of the macadamia nuts occurs, preparation should take place under clean, hygienic and ideal conditions. The following aspects should be adhered to:

- Equipment (tubs, knives etc.), as well as working and drying surfaces (racks, mats etc.) and preparing and storage rooms, should be cleaned regularly.
- Personnel should be healthy, and have the possibility to wash themselves, or at least their hands (washrooms, toilets) and wear clean, washable overgarments.
- Water used for cleansing purposes must be free from faeces and other contaminants.
- Animals or animal faeces must not come into contact with the product.

3.1.3. Packaging and storage

Bulk packaging

Macadamia nuts intended for export to Europe are usually packed in bulk in metal cans or in shrink-packaging made out of steam-impermeable, sealable foils (e.g. polyethylene, polypropylene) in units of 10 kg. Before the cans are soldered or the bags sealed, an inert gas (e.g. nitrogen or carbon dioxide) can be added, in order to prevent the contents from becoming rancid.

Consumer packages

If the macadamia nuts are not to be packaged in bulk containers in the country of origin, but sealed in consumer packages, then this packaging should fulfil the following functions:

- Protect the macadamia nuts from loss of aroma and against undesirable smells and tastes from its surroundings (aroma protection).
- Protect the contents against damaging.
- Offer sufficient conservation properties, especially against loss or gain of moisture.
- Provide a surface area for advertising and product information.

The following materials can be used as **product packaging**:

- Single-layer plastic bags (polyethylene or polypropylene)
- Aluminium tins
- Glass containers
- Nets for unshelled buts

Transport packaging

Some form of transport packaging is required in order to ship the bulk or nuts packed for consumers. In choosing a type of packaging, the following should be heeded:

- Transport packaging made, for example, out of cardboard, should be strong enough to protect the contents against being damaged by outside pressure.
- The packaging should be dimensioned to allow the contents to be held firmly, but not too tightly in place.
- The dimensions should be compatible with standard pallet and container dimensions.

Information printed on transport packaging

The transport packaging should display details of the following:

- Name and address of the manufacturer/packer and country of origin
- Description of the product and its quality class
- Year harvested
- Net weight, number
- Batch number
- Destination, with the trader's/importer's address
- Visible indication of the organic source of the product[19][18]

[19] When products from organic farms are being declared as such, it is necessary to adhere to the requisite government regulations of the importing country. Information concerning this is available from the appropriate certification body. The regulation (EEC) 2092/91 are applicable to organic products being imported into Europe.

Storage

Unshelled macadamia nuts with a moisture content of 10% can be stored for 4 weeks in a well-ventilated place, yet should be shipped as quickly as possible to be processed. Nuts intended for home use can be stored away from direct sunlight, in a dry and ventilated place. They should be placed in piles of no higher than 25 cm and moved around weekly. Nuts both shelled and unshelled with an optimum moisture content of 1.5 % can be stored in air-tight containers for up to 6 months, and at 1-4°C for 12 months.

Mould growth can either be prevented with

a) Temperatures below 7°C or

b) relative humidity below 20%

Packaged macadamia nuts should be stored in a dark place at low temperatures (below 18°C) and relative low humidity.

If the organic product is being stored in a single warehouse together with conventionally grown macadamia nuts mixing of the different qualities must be avoided. This is best achieved using the following methods:

- Training and informing of warehouse personnel
- Explicit signs in the warehouse (silos, pallets, tanks etc.)
- Colour differentiation (e.g. green for the organic product)
- Incoming/dispatched goods separately documented (warehouse logbook)

It is prohibited to carry out chemical storage measures (e.g. gassing with methyl bromide) in mixed storage spaces. Wherever possible, storing both organic and conventional products together in the same warehouse should be avoided

[18] Organic products must be protected from contamination by non-compliant substances at each stage in the process, i.e. processing, packaging, shipping. Therefore, products originating from a certified organic farms must be recognisably declared as such.