United Nations
Environment Programme-UNEP

United Nations Educational
Scientific and Cultural Organizatio
UNESCO

International post-graduate course in ecological approaches to resources development land management and impact assessment in developing countries

III. Vol. 3

German Democratic Republic

UNEP/UNESCO

INTERNATIONAL POSTGRADUATE COURSE IN ECOLOGICAL APPROACHES TO RESOURCES DEVELOPMENT, LAND MANAGEMENT AND IMPACT ASSESSMENT IN DEVELOPING COUNTRIES (EMA)

held at the Technical University Dresden,
German Democratic Republic

organized by

United Nations Educational, Scientific and Cultural Organization (UNESCO)

and

the United Nations Environment Programme (UNEP)

Centre for Protection and Improvement of Environment (Berlin) of the Ministry of Environmental Protection and Water Management of the German Democratic Republic in cooperation with the Technical University Dresden

Subject III: Agro-ecosystems: Land-use planning with special reference to infrastructure and regional planning

STUDY MATERIAL
elaborated by a team of authors under G. Franke and A. Pfeiffer

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III. 2. Ecology and cultivation of important crops
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Volume Three

Subject III: Agro-ecosystems: Land-use planning with special reference to infrastructure and regional planning

III.2.2. Cultivation of important crops

III.2.2.1. Starch plants

Rice (Oryza sativa)

For approximately 60 per cent of the world's population, rice is the most important basic food. The annual crop of the world is about 414 mill. t and thus somewhat below the wheat crop but, due to a higher yield per unit of area (about 23 dt/ha), it is obtained from a smaller area of arable land than wheat (about 15 dt/ha). The original habitat of this grain, which was already grown 2,700 years B.C. as can be proved, presumably is South-east Asia. Its present distribution between 40° south latitude and 47° north latitude.

Although rice is not among the aquatic plants, it can thrive while it is continuously inundated (lack of oxygen) due to the formation of an air-conducting tissue in the roots. Since a constant optimum water supply ensures higher yields, the cultivation of water rice is preferred. While the traditional cultivation of water rice on the basis of small holdings, cattle as draught animals and manual labour on fields already flooded with water (by an series of manual operations, the soil is turned into a muddy structure) is still carried on, there are many other cultivation methods including the fully mechanised process. A precondition for the latter is the exact controllability of the water. Rice growing without irrigation is not distinguished from the conventional grain growing methods. Remarkable successes in breeding, achieved during the last 15 years, have led to semi-dwarf varieties with a distinct stability, intense tillering and a high capability of nutrient utilisation (intensive varieties). Under tropical climatic conditions where rice can be grown three times a year, yields can be obtained of

more than 100 dt/ha/year. Field tests conducted in Cuba have shown what a potential is actually available since one cultivation yielded 130 dt/ha.

The hard hulls of the rice kernel must be removed before eating. To obtain the desired white grain, rice is hulled and then polished (removal of the fruit and seed hull and of the germ). In these processes, valuable substances are lost so that a diet consisting mainly of rice in the polsihed state leads to the beriberi disease (lack of vitamin). Modern processing methods enable the preparation of white rice while important substances contained in it are preserved. Rice is not suitable for the preparation of bread.

Wheat (Triticum spec.) and maize (Zea mays)

Although 42 per cent of the world's wheat production is grown in the subtropics and tropics, wheat is not among the tropical useful plants.In a suitable situation, wheat can be cultivated both at the equator and up to the polar circle. Together with rice, wheat and maize constitute two thirds of the world's cereal production.

The beginning of wheat cultivation dates back to prehistoric times. The original habitat of the initial forms of wheat are probably situated in South-west Asia. Today, it covers the largest area among the cultivated plants of the earth (about 239 mill. ha). Of the many species and the largest diversity of varieties, seed and bread wheat and the durum or macaroni wheat have gained the greatest importance. Due to the numerous varieties and ecotypes, wheat can be grown as summer wheat in the cool and moderate climate, as summer and winter wheat in the moderate and subtropical climate and as summer wheat at altitudes of the tropical climate both under humid coditions and under drier (semi-arid) conditions in steppe regions. In the tropical plain country with high temperatures and a high atmuspheric humidty, wheat is heavily infested

by pests, especially rust fungi, and therefore is not suited for being grown in this region. Throughout the world, wheat is harvested practically in every month of the calendar year because of its wide distribution. Just like with rice, intensive varieties have provided the preconditions (Soviet Union, Mexico) for high yields per unit of area.

Although maize also belongs to the cereals, it is sometimes reckoned among the root and tuber crops depending on the method of cultivation selected. Its area under crop in the world is about 134 mill. ha (yield per hectare of grain-maize is about 25 dt/ha). From its centre of domestication in the region of the present Mexico, maize has proved to be worthy of growing up to the polar circle, starting from the tropical plain country, due to its genetically conditioned great variety of forms and its capability of adaptation (75 per cent of the world's production of grain-maize is grown in the subtropics and tropics). A secure cultivation of grain-maize is, however, only given when its pronounced heat requirements are met. As to the degree of water utilisation, wheat requires 513 l for 1 kg of plant dry matter, maize 368 l and sorghum millet 322 l. The good adaptability of maize and wheat, and also that of rice, should not obscure the fact that at the equator throughout the year the 12-hour light-day is invariably prevalent while in the temperate latitudes the light-day comprises 16 hours in summer. Since many varieties distinctly react to the light conditions, a distribution of varieties along the latitudes is frequently connected with less disadvantages than that along the degrees of longitude.

Millets and sorghums

These are a great number of grain crops of the family of grasses. A subdivision into the groups of the large-seeded sorghums and the small-seeded millets is common.

Originally, millets and sorghums were very important as foods. Changed feeding practices with a pronounced trend towards rice and wheat products have led to the fact that millets and sorghums as basic foods are restricted to the dry regions of Africa and Asia. Millets and sorghums, however, gain in importance as fodder grains.

Of the large-seeded sorghums, more than 30 species are cultivated (about 48 mill. ha of land under this crop). They have wide leaves and a strong main stalk filled with marrow and, thus, resemble maize. The inflorescence can exhibit a loose or a dense panicle in the form of a cob. Due to their high demand for heat and the relatively low other requirements, hot semi-arid regions are particularly suitable for their cultivation in the tropics. Under such site conditions, they produce higher and more reliable yields than maize. The seeds are used for the preparation of a gruel and, in the form of lour, for baking flat cake. Use as a green forage (younger green forage most be allowed to wilt for a few hours in order to reduce a possible content of hydrocyanic acid) is widely distributed. Species and varieties which show a high content of sugar (8 to 15 % of saccharose) serve for the production of syrup and crystal sugar.

The small-seeded millets (about 71 mill. ha of land under this crop) cover any species of grass whose seeds are used as food or feeding stuffs. In parts of Europe, the bog millet (Panicum) and the foxtail millet (Setaria) (used as bird-food) are known. Within the tropics and subtropics, the millets show, especially in the dry regions, a distribution that is similar to that of the surghums. A few of them are restricted to certain areas such as teff grass (Eragrostis) which is economically important in Ethiopia only where it is used as food (2,500 to 3,000 seeds per gramme. A high demand for heat ans susceptibility to low temperatures is typical of the millets. Due to their generally slow development in the juvenile stage, they are exposed to the danger of a heavy weed infestation.

The world's average yield of sorghums is about 13 dt/ha (peak yields of intensive varieties amount to 50 dt/ha). The great variety of millet species results in an average yield of 6.5 dt/ha. On the whole, the resources which can be developed throughout the world are high for this cereal, too.

Cassava (Manihot esculenta)

This plant having fleshy rootstocks is also called manioc or yuca (Spanish). Its habitat extends from the Amazon region through Central America to Mexico. It is a perennial plant whose roots are ripe for harvesting after 9 to 12 months but may remain at the plant for a period of 2 to 3 years. Unlike other root and tuber crops, the area under crop must not be harvested until a certain date completely. The increasing proportion of ligneous fibres in the roots with increasing age of the plant is a disadvantage with respect to the use-value. The tubers develop by a secondary thickness growth of individual roots, reach a length of 50 cm (sometimes up to 1 m), a diameter of up to about 15 cm and a weight of anything between 2 and 4 kg (even up to 25 kg). Due to the growth period of several years, the cultivation of cassava is restricted to the tropical region since even in the subtropics, the hot summer months will not be sufficient for the development of tubers ripe for harvesting. Cassave is subject to propagation by cuttings having a length of anything between 15 and 20 cm which are cut out of the ligneous stalks reaching a length of up to 3 m. As a plant that is typical for being grown for subsistence or meeting the local demand, cassava is frequently grown on small areas only where, more often than not, a mixed cultivation of batatas, maize or other plants is effected. To facilitate harvesting and to ensure a sufficiently loose condition of the soil, it is common usage to plant the cuttings on dams. Under favourable conditions, yields of 750 dt/ha have been achieved; the world's average yield is about 80 dt/ha, however. As compared to the traditional export crops (cocoa, tea, coffee), purposive breeding was not carried out in the past.

The whole cassava plant, especially the tubers, contain the glycoside Manihot toxin (corresponds to linamarin) from which the extremely toxic hydrocyanic acid is separated by the encyme linase. Therefore, the eating or raw cassava or an improper preparation of it may lead to fatal hydrocyanic acid poisoning. Actually, deaths are seldom.

The peeled tubers are used which may contain up to 35 per cent of starch; before use, they are watered for a prolonged period of time and the water is changed to remove the Manihot toxin in the boiled condition; frequently, the tubers are reduced to mash. Roasting and stewing are common ways of preparing. There are also "sweet" types which contain very small amounts of Manihot toxin so that they may be eaten in the raw condition. Without any difficulty it is possible to obtain cassava starch in a commercial manner or to dry the peeled tubers, undivided or sliced, and to produce cassava flour. Due to its high content of starch, cassava is very substantial but is a quite unbalanced nutrition of carbohydrates (contains only about 1 per cent of protein).
Therefore, malnutritional diseases due to the lack of protein are frequently found among the poorer strata of the population.

Yam (Dioscorea spec.)

The taste of yam tubers may be compared with that of potatoes when cooked in the same way. There are many different species of yam and, consequently, considerable differences in shape, size and weight of the individual tubers containing up to 25 per cent of starch. The weight of a mature tuber is between 4 and 8 kg on an average. When special cultivation methods are used, record tubers having a length of about 2 m and a weight of 80 kg can be obtained. The number of tubers per plant is small and frequently the plant produces only one big tuber. For the propagation of this monocotyledon, small tubers or parts of the upper portion of big tubers rich in eyes are used. Since yam is a climbing or twining plant with a herbaceous stalk, stakes or espaliers of wire or timber having a height of at least 1.80 m are required.

If the possibilities for climbing are insufficient, the yields will be impaired. Further, the formation of ridges or mounds at spacings of 1.2 to 1.5 m and a height of about 90 cm is in common use and varourable for the development of tubers. This shows that the cultivation of yam is rather time-consuming and calls for the expenditure of much work, and it is also difficult to mechanise it. A full mechanisation of cultivation is impossible with the varieties available today. That is why yam is among the more expensive root and tuber crops in the markets although peak yields of 600 dt/ha are possible (in extensive cultivation rarely 100 dt/ha). Although species of yam are native to America, Africa and Asia and are cultivated there, particular cultivation centres have not developed for the above reasons. A more pronounced distribution of the yam cultivation is found in the West Indian Islands, the Pacific Islands, in South America and various areas of Africa and South-east Asia. A leading position, though with a declining trend, among tuber and root crops is occupied by yam in West Africa (Nigeria). In the temperate climate, this plant is unknown and scarcely distributed in the subtropics because temperatures below 20 °C exert a detrimental effect on growth and yield (otimum are 25 to 30 °C and more than 1,500 mm annual precipitation associated with a dry period). The duration of the growth period until the ripness of the tubers shows differences between the species and varieties from 6 to 12 months.

Since all species of yam contain certain amounts of alkaloids, tannins and saponins, that is, more or less toxically acting substances, watering and boiling is necessary before eating. Usually, the content of alkaloid in cultivated yam is almost insignificant. Yam tubers are eaten in the cooked, roasted, and baked state and as a pap. A special, time-consuming preparation by mashing results in the fufu very popular in West Africa.

Batatas (Impomoea batatas)

Frequently, batatas are called sweet potatoes. Since the batata has nothing in common with the potato and its tubers are not always of a typical sweet taste, the term of sweet potato should not be used. It is an annual plant of the family of the twining plants whose original habitat obviously is the tropical climate of America. Today, this plant, which comprises a number of provenienees and varieties which can hardly be overlooked, is distributed up to the subtropics and the temperate climate with a distinctly warm summer (Bulgaria, south of the Soviet Union). This considerable range of cultivation apparently is due to the relatively short vegetation period of the batata between 3.5 to 5 months. Thus, it can be cultivated in any place where, during its period of growth, the mean temperature is between 20 and 22 °C.

Propagation exclusively takes place on the vegetative way. The most expedient method which also is widely used (no loss of eatable substance) is the planting of cuttings. The still green tendrils of the batata are cut into pieces of 25 to 30 cm in length and planted in adequately moist soil. In regions of cultivation, where fresh tendrils are not available during the planting time, whole or divided tubers are used for planting. Less tubers are required when tuber sprouts are bred. For this purpose, tubers are put into a moist sand bed where numerous well-rooted sprouts will develop after 4 to 6 weeks. They can easily be separated from the parent tuber and then planted. The tubers of this cultivated plant grown in earthed-up soil have reached maturity when the major part of the tendril lying on the ground and their leaves have become yellow and tend to die away. During harvesting, the tubers having a thin peel must be handled carefully. They may have a weight of up to 1000 g (but even 2 to 3 kg). Maximum yields amount to 400 dt/ha, usually the crop yields rarely more than 100 dt/ha.

The multifarious ways of using the plant are remarkable. Young leaves are suited for the preparation of a sort of spinach. Leaves and tendrils are a good feed for animals, and since the tubers are eaten by humans, they can also be used as feed for animals. The substances contained in the tuber show a high dependence on the site of growing; in the tropics, they may contain up to 20 % of starch and 6 to 10 % of sugar while, in the temperate climate with distinctly warm summers, up to 30 % of starch, 2 to 4 % of sugar, and up to 2 % of protein may be reached. The tubers are cooked and baked, roasted in oil, processed into flour or used for the preparation of starch, syrup or alcohol. Preservation (tins) in the form of a vegetable is also possible (Japan). The poor capability of being stored is a disadvantage of the batata tubers so that consumption within a week is advisable. Otherwise, temperatures between 12 and 15 °C and an atmospheric humidity of from 85 to 90 % are required to keep well matured tubers fresh over a prolonged period of time.

Potatoes (Solanum tuberosum)

The potato is among those cultivated plants that can be grown in almost all climatic zones of the world provided the temperature and light conditions are adequate. Factors limiting the cultivation are the high susceptibility to frost of all parts of the potato plant and a poor formation of tubers at high temperatures such as occurring in the flat regions of the tropics. With well balanced day and night temperatures, about 30 °C can be considered as approximately critical limit for the formation of tubers. The original habitat are the highlands of South America.

By breeding efforts, the originally pronounced short-day types of the wild forms were adapted to temperate climatic conditions so that the present cultivation of today's varieties under tropical conditions frequently is associated with very poor

yields and only late varieties (which due to the quicker growth only reach the cultivetion time of early varieties) can be successful. The breeding of locally adapted varieties is only in the beginning in the tropics. Recently, the growing of potatoes has been subject to considerable promotion in many developing countries because of their importance to nutritional physiology, their good ecological adaptability and their good storing and transport capability. In 1981, the centre of potato cultivation now as before has been Europe with 10.3 mill. hectares (132 dt/ha) whose share in the world's production declined from about 85 % (1948/52) to about 57.5 % at present (decline = 2 mill. ha in 10 years). To the contrary, in Africa, the land under the potato crop has doubled within 10 years and today is about 585,000 ha (in 1979, GDR: 549,000 ha) with an average yield of 87 dt/ha (GDR: 223 dt/ha). In Asia, the cultivation of potatoes has also gained considerably in importance and, after an increase by 1 mill. ha in the last ten years, covers 3.2 mill ha in 1981 (117 dt/ha). The native continent of the potato (South America) shows a constant area under this crop of about 950,000 ha with an average yield of 111 dt/ha. In North and Central America, about 705,000 ha (269 dt/ha) are cultivated, exhibiting a slightly declining trend.

The official FAO statistics show 126 countries where potatoes are grown.

Taro (Colocasia esculenta), tania (Xanthosoma sagitti folium), arrowroot (Marant arundinacea) and other root and tuber crops

In the tropical and subtropical climatic regions, there are - besides the most important root and tuber crops discussed in detail - many other plants which develop edible tubers or rhizomes.

The taro (also called eddo, dasheen or cocoyam) originates from East Asia and Polynesia. Its large, shield-like, undivided leaves with long petioles grow from a thickened underground trunk (rhizome). They reach a height of maximum 2 m. For planting, only the top part of the rhizome is used. Until the rhizomes are mature, up to 14 months may be required. The starch content of this tasty tuber crop is between 15 and 25 per cent. Oxalate crystals may occur which must be removed by changing the water for boiling otherwise the throat may be irritated during eating. A certain capability of being stored and transported of the crop enables exports. For example, a considerable part of the taro production of Cyprus is exported to England (London) where this native produce is readily bought by the large number of emigrated Cypriots.

Tania, a crop also developing tuberous rhizomes, is closely related with taro and originates from the tropical America. Today it is distributed over the entire tropical region and it is grown almost exclusively for subsistence. The daughter tubers are distinguished from the oval-oblong or oval-roundish taro tubers by a smooth appearance and a more tuberous thickening towards the base.

An interesting tuber crop is the arrowroot. The original habitat of this shrub-like plant reaching a height of 1 to 2 m is the tropical region of America. The leaves are arranged opposite each other and grow from the rootstock and the nodes of the stalk. The most important region of cultivation are the West Indian Islands. The distinctly thickened rhizomes, growing from the stalk base and reaching a length of 25 to 45 cm, consist of a great number of segments. They require 10 to 12 months to reach the highest starch content (about 25 per cent) and are primarily used for the production of starch.

A particularly great number of other plants producing tubers are found in the region of the original habitat of the potato,

in South America. Worthy of note is oka (Oxalis tuberosa) exhibiting trifoliolate leaves resembling clover and up to 7 cm long irregularly shaped tubers. Anu (Tropaeolum tuberosum) grows in the same region as oka. It is a climbing plant also producing irregularly shaped tubers. In the original habitat of the potato, ulluco (Ullucus tuberosus) with oblong roll-shaped tubers of up to 20 cm in length is found.

At present, the goa bean (Psophocarpus spec.) is gaining in importance of which a few species and varieties produce both tubers and remarkable amounts of edible seeds. The problem whether a large-scale cultivation of this plant, which has been used locally for a long time (East Asia), can be solved at present has still to be found out.

III. 2.2.2. Oil plants

Oil palm (Elaeis guineensis)

Of all plants providing oil, the oil palm supplies the highest oil yield. In case of intensive cultivation of heavily yielding varieties in well suited sites, about 30 t of fruit bunches per hectare can be harvested in a year within the period of the highest yield of a palm stand today. From this, 7 to 8 tons of oil can be produced. Although the use of palm oil has been known in Africa from the year of 1466, and the first palm oil was marketed in England in 1790, the arrangement of large plantations was started only after 1900 in West Africa, from where the oil palm originated, and also in Indonesia and Malaya. At this time only suitable machines for the extraction of the palm oil were available.

The present geographic range of the cultivation of oil palms comprises in West Africa a tract of land having a width of 50 to 200 km along the coast of the Gulf of Guinea with a main area of cultivation in Nigeria, and further areas in Guinea, Sierra Leone, Ivory Coast, Ghana, Togo, Benin, Cameroon, Gabon, Zaïre, Angola. In the Zaïre basin, the cultivation of oil palms

extends far into the continent up to the East African lakes. In Asia, important countries growing this crop are Indonesia (Sumatra) and Malaysia. The oil palm is gaining in importance also in South and Central America (especially in Brazil and Colombia. The most important oil palm growing countries are Malaysia, Nigeria, Indonesia and Zaire.

The climatic requirements of the oil palm restrict an extension of the cultivation. Oil palms require a practically constant temperature between 24 and 28 °C. Thus, its cultivation is in essence limited to the regions between 10° to the north of and 10° to the south of the equator and to altitudes up to 500 m. For thriving well, sunshine (possibly 5 to 6 hours per day), rainfall of 1,500 to 3,000 mm per year and a deep and permeable soil are additionally required.

Botanically, the oil palm is not significantly distinguished from the coconut palm. Distinct features distinguishing it from the latter are the stronger and denser pinnate leaves, the flowers and infructescences and the stubs of the broken off leaves which remain at the trunk for a long time. These stubs are shed only during the later age of the tree. This shows that oil palms do not exhibit the slender and smooth trunk of the coconut palms.

In each pinnate leaf axil, a unisexual inflorescence develops after 4 to 5 years and, at one and the same palm, a periodic change between male and female inflorescences takes place. The infructescences weighing anything between 15 and 25 kg comprise 800 to 4,000 plum-like (3 to 5 cm long) fruits. These are stone fruits. The main quantity of the oil is contained in the pulp. The seeds (known as palm kernels) also contain oil. At the time of ripening, the stalk of the fruit bunch having the thickness of an arm must be cut through. With older palms it is necessary to climb up the trunks. After about 30 years, the palms have

reached such a height that harvesting becomes quite difficult. Since, at this time, the yield starts declining, new trees should be planted. Young plants can only be obtained by seeds. Since the seeds show a poor readiness to germinate, special incubators are used for warm and moist treatment in modern cultivation practice.

The pulp must be processed within 24 hours after harvesting in order to prevent the formation of free fatty acids. The oil is extracted from the pulp which is mashed by pressing or centrifugation. Then the seeds are removed from the stony shell and pressed out on the spot or exported in the dried state. After raffination, the palm oil is used especially for the production of margarine and shortening. The residue from pressing contains about 15 per cent of raw protein and is used as feed for animals.

Coconut palm (Cocos nucifera)

From the angle of botany, the fruit of the coconut palm is not a nut but a stone fruit. A thin fibre hull is under the external leathery skin; a stone shell follows the hull. In the interior, the pulp is attached to the stone shell. In the dried condition, the pulp is called copra. The cavity inside the coconut in the unripe state is completely filled with fruit water. At the time of maturity, the content of fruit water is reduced to about the half of the original amount so that ripe coconuts can be identified by the babbling sound that can be heard when the fruit is shaken.

The native region of this slender palm reaching a height of up to 25 m is Melanesia (region between 145° and 180° of east longitude, to the south of the equator up to the tropic, islands between New Guinea (West Irian, Papua) and the Fiji Islands). All palms belong to the monocotyledons and, in contrast to the top-trees with trunk, branches, twigs and leaves, are so-called tuft-trees which carry a dense tuft of usually large pinnate

leaves on a more or less high lignified trunk, directly and only at the top arising from the vegetation cone. Palms do not show a secondary thickness growth. In the youth, only the leaf tuft can be seen which arises from the germ stalk. The growth in length which starts at a later time is effected exclusively by an extension of the trunk which is column-shaped and thick right from the beginning.

During the germination of the coconut, a suction organ is formed in the interior of the fruit which disintegrates the nutrients stored in the pulp and makes them available for the plantlet. Since the stone shell cannot be broken by the plantlet, one of the three germ holes in the shell is opened. The inflorescences develop in the high varieties during the period from the 6th to the 8th year of life in the axils of the pinnate leaves. The same inflorescence has both male and female flowers. The male flowers have already faded when the female flowers start opening. Self-fertilisation is impossible. Low-growing varieties become mature at an earlier time and are self-fertilising. Crossbreeding the two forms results in heavily yielding descendants which, however, is not suitable for propagation (segregation).

All parts of the coconut palm can be used:
Pinnate leaves for roofing, wood for construction, vegetation cone as vegetable, fibre hull for coir production, stone shell as fuel, pulp for eating in the fresh condition, for the preparation of rasps or for the production of oil. For harvesting, the palms must be climbed (every two to 3 months). The average yields are between 40 and 60 nuts per palm (up to 200 nuts per palm are possible). The copra contains about 60 % of oil which is used as edible oil and for technical purposes. The fruit water, especially that of unripe fruits, is drinkable. Mixed with unripe pulp, the so-called coco-milk is obtained.

Olive tree (Olea europaea)

The native region of the olive tree is the Mediterranean area; beyond this region only small areas of cultivation of lesser importance have developed (USA, the Argentine, Australia). This regional limitation of cultivation is also mirrored in the production of which 95 % are provided by the countries of the Mediterranean area and Anterior Asia. Italy ranks first with about 30 % of the world production. Then follow Spain (25 %), Greece (13 %), Turkey (8 %) and, with smaller shares, Portugal, Tunesia, Morocco, Algeria, Lebanon, Cyprus.

The olive tree ranks among the oldest cultivated plants. It is mentioned in the oldest documents of the Greeks, Hebrews and Egyptians and may have plyed a part already in prehistoric times. Climatically favourable areas for cultivation of the olive tree have a mean annual temperature of 15 to 20 °C. Temperatures below 0 °C lead to damages to the leaves. Higher degrees of cold exert a detrimental effect on twigs and branches and temperatures below - 8 °C cause severest frost damage. Rainfall amounting to anything between 500 and 700 mm per year is sufficient. Under favourable soil conditions, even 200 mm will be sufficient (Sfax, Tunisia). On pronounced fertile and moist sites, the olive tree will grow exuberantly but the fructification remains insufficient.

The olive tree is propagated exclusively vegetatively because propagation by seed leads to a considerable segregation of the descendants. Preferred methods of propagation are grafting and by cuttings. A peculiarity is a tissue at the stem base from which both sprouts and roots arise. The sprouts can be used for new planting or themselves form a thick trunk. Old olive trees have a height of up to 20 m, a widely extending top (having a circumference of up to 50 m) and frequently possess bizarrely shaped and even hollow stems.

The fruit of the olive tree is the olive, a stone fruit having

a colour from light yellow to black-blue. The pulp contains 23 to 60 % of oil, the seeds 12 to 15 %. For the production of oil, the whole fruit is ground into a mash. The oil pressed out of the latter is used as edible oil. From the residues of this pressing operation further oil is extracted for technical purposes (soap production).

While for oil production special varieties of the olive tree having high yields of mass and a smaller fruit, varieties having large fruits and thick flesh are used for the preparation of olives for eating. For harvesting, olives are stripped from the trees by means of suitable tools, the trees are shaken or the fruits gathered by beating. Olives to be eaten should only be picked. To reduce the labour required for harvesting, fruit-removing chemicals and vibrating or shaking equipment in connection with collecting devices are used. An unfavourable fact is the frequently pronounced yield alternance (a full crop is yielded only every second year).

Groundnut (Arachis hypogaea) also called peanut

The groundnut belongs to the Leguminosae and is native to South America. Due to its very high nutritive quality (the seeds contain up to 55 % of oil, 24 to 35 % of protein, 3 to 8 % of carbohydrates, vitamin B and E) and its excellent taste, the groundnut is among the most importand food crops in the tropical and subtropical climate region. The major part of the production is consumed in the producing countries.

Beyond the tropics and subtropics, the most important areas where the groundnut is grown are situated up to the 42nd degree of latitude (Bulgaria, southern part of the Soviet Union, North China) although susceptible varieties may suffer damage already at a temperature of 15 °C. Since a great number of types and varieties are available, early-ripe varieties having a vegetation period of 3 to 5 months can be grown in all places where

during this period adequate temperatures (summer) are given. The groundnut is an annual herbaceous plant whose upright varieties reach a height of 70 cm. From the rapidly growing tap-root, numerous secondary roots arise in the upper layer of the soil; on the latter roots, the nodes typical of leguminoses develop by sybiosis with nodule bacteria. The nocturnal sleeping position of the short-petioled egg-shaped leaves having a length of about 2 to 5 cm is remarkable. The flowers are arranged in short-petioled inflorescences in the leaf axils. After fertilisation (usually self-fertilisation), new growth starts below the ovary. Due to the extension associated with this, an infructescence is formed which is positively geotropic, that is to say, it growth towards the earth and penetrates into it. At a depth of about 5 to 10 cm, the growth of extension ceases and now the fruit starts growing. Finally, it lies horizontally in the ground.

Because of its tap-root, the groundnut plant is relatively resistant to dryness. The soild should be light and have a good water volume and adequate aeration. Heavy and severely encrusted soils are unsuitable because it is difficult for the infructescence to penetrate into the soil and the harvest is rendered difficult.

Groundnuts are cultivated in ridges similar to those of the potato. Favourable spacings between plants are about 40 x 20 cm. Cultivation operations are only allowed during the period until the beginning of the flowerin period because the infructescences are very brittle and easily brea away when touched. The most favourable time for harvesting must be ascertained with every care because the fruits ripen over a prolonged period of time because of the different flowering times. Test digging is necessary in order to find the most favourable period (premature harvesting will inevitably gather a high proportion of unripe

fruits, too late a harvest is associated with a high proportion of germinating seeds). For harvesting, the tap-root of the plant must be cut and the whole plant with the fruits adhering to it drawn out of the soil. For drying, the plants usually are left in the field (piles, sheaves) until the dry pods can be separated. Besides manual harvesting, there are already fully mechanised methods.

In the world (1981), 19.4 mill. t/year were harvested (with pods); important countries for the production of the peanut are India (6.0 mill. t), China (3.5 mill t), USA (1.8 mill. t), and Senegal (0.9 mill t, in 1976 1.1 mill. t, however). Good yields are anything between 15 to 25 dt/ha while peak yields amount to 35 dt/ha. The world's average yield only amounts to 10 dt/ha, however. When processing the nuts, losses due to hulling of 26 to 50 % may be involved (depending on the variety). Large-seeded varieties having a lower oil content are used for food nuts (roasted and salted). Small-seeded varieties having a higher oil content are used for the production of edible oil. The press cake (about 40 % of protein) is an appreciated concentrated feed.

Sesame (Sesamum indicum)

The sesame plant is native to the summer rainy region of tropical Africa. In times of early history, sesame was brought to India and China so that a second centre of development was cultivated in these areas. The importance of this plant is due to the oil content of the seed (about 50 %). The oil produced is very tasty and very durable oil. In the world market, it is the edible oil that attains the highest prices.

Sesame is an annual erect herb reaching a height of from 1 to 2 m. The square or hexagon stalk is more or less branched

depending on the variety. The leaves also exhibit quite distinct differences in shape. There are oblong egg-shaped, three-lobed to five-lobed leaves or those with a continuous edge. A tap-root enables the plant to draw water from the deeper layers of the soil. From this, a relatively good resistance to dryness is derived. The chiefly white or rosy flowers having a length of about 3 cm grow individually or in groups in the upper leaf axils. They form 2 to 3 cm long and about 0.5 to 1 cm wide multi-cell capsules. When mature, the capsules burst and allow the seeds having a length of 1.5 to 4 mm to escape. The thousand kernel weight of the very small seeds is about 2 to 6 g. Sesame cultivation is favourable at relatively high temperatures; the optimum is about 25 °C. The plant is highly susceptible to frost. In the warm temperate climate, early ripening varieties may be grown when sowing is after the last late frosts and harvesting takes place before the first autumn frosts. In the stage of germination, temperatures of 18 °C will exert an influence that is detrimental. Therefore, the cultivation boundaries of sesame are between 42° north latitude (Bulgaria) and 35° south latitude.

The very small seeds call for a well prepared seedbed (similar to that of poppy). About 2 to 4 kg are drilled, for broadcast sowing, 5 to 8 kg are required. The use of herbicides is only possible under certain circumstances.

Harvesting is difficult because the capsules ripen non-uniformly so that high losses may occur due to the bursting of capsules. It has been possible to breed varieties which will not burst and, thus, are suitable for combine-harvester harvesting. It is interesting to know that the tough capsules at first achieved by breeding could not be gathered in by the combine harvester. Today, there are suitable varieties with thin-walled capsules.

The yields are low because of the mainly extensive way of cultivation. Frequently, they are only 3.5 to 5.0 dt/ha. With intensive cultivation, 10 to 20 dt/ha have been reached. Top yields in test stations are more than 25 dt/ha.

The most important sesame producing countries are (1981) India (500,000 t), China (401,000 t), Sudan (200,000 t). A small part only of the production is used for oil production. The hulled seeds are directly used as food in the producing countries. The good durability of the oil is due to the presence of sesamin and sesamolin (antioxidants). Since these two substances are easily detectable, in many countries regulations have been issued according to which small amounts of sesame oil must be added to the material for the production of margarine in order to have an easily detectable feature to distinguish it from butter.

III.2.2.3. Sugar plants

Sugar cane (Saccharum officinarum)

Sugar is defined as a number of substances having a sweet taste, belonging to the carbohydrates and contained in the cell sap of the plants. Of the various types of sugar (grape sugar, fruit sugar, malt sugar, and others), can sugar (saccharose) is economically the most important type. Can sugar (a disaccharide) is chemically built up of the two monosaccharides glucose and fructose.

For the production of white sugar, only the sugar cane and the sugar beet are economically of importance. A certain competition between these two plant species only exists in the boundary and transitional zones between sugar can cultivation and sugar beet growing in certain subtropical areas. In the tropics, the sugar cane is clearly superior to the sugar beet. Presumably, the sugar cane is native to New Guinea and the neighbouring islands (to the north of Australia). Today, this plan is found in all parts of the world betwee 35° north and 35° south latitude. The most important producers of sugar cane are India with 150 mill. t,

Brazil with 154 mill. t, and Cuba with 67 mill. t of cane. These figures illustrate the means of transportation and the labour involved for the harvested cane.

The optimum of growth of sugar cane is at 30 °C. Already at 15 °C, the growth will be largely inhibited. The demands for rain of this plant are high (at least 1,200 mm); in the juvenile stage the rainfall should be moderate, in the main period of growth it should be ampler, and during the harvest no rain should fall.

Like maize, sugar cane is a subterraneanly tillering huge grass. The massive stalk may reach a height of 6 m and a thickness of 2 to 5 cm. The 1 to 2 m long grass-like leaves are finely serrated along the edges and hard and sharp due to silicification. For propagation stalk cuttings are used which should have at least 2 to 3 eyes (are found at the nodes). It is also possible to place whole stalks in furrows having a depth of about 45 cm (extensive cultivation). In the course of the cultivation operations, the furrows are gradually levelled. To favour tillering, the young plants are earthed up.

Depending on the site conditions, sugar cane is mature for cutting after 10 to 24 months. The stalks are cut off as deep as possible while the leaves and the green top are removed. Today, harvesting machines are available which process the cane commercially. In contrast with the sugar beet which can be stored, sugar can should be processed within 24 hours after the harvest. The pressed out plant sap is processed into white sugar according to the same method that is also used for the sugar beet. The sugar obtained is not distinguished from that obtained from the beet. A utilisation of the sugar cane fields over a period of several years (2 to 3 years and even 10 years and more) is common by harvesting the re-grown plants. With a period of growth of a year (12 months) an average crop of 50 t/ha of cane can be expected. Peak yields amount to 100 t/ha and more.

The content of saccharose of about 9 to 16 % is lower than that of the sugar beet.

Sugar as a sweetener and food is indispensable for human nutrition. Sugar is also gaining in importance as a raw material for the chemical industry for the production of detergents, wetting agent and emulsifying agent, surface coating materials and highly polymerised compounds (sucrochemistry). It is a raw material that can be produced newly every year in contrast to coal and crude oil.

III. 2.2.4. Fruit

Citrus (Citrus spec.)

The genus of Citrus comprising many species and forms is native to South-east Asia (in the region between India, Japan and Indonesia). In the world's production, oranges rank first. Then follow the mandarins and tangerines while the third place is taken by the lemons and limes; the last economically important group are grapefruit. Worthy of note are also the cedrate, the bitter oranges and the bergamots.

All species of citrus require much sunshine. Parts of them only show an insignificant susceptibility to short frost periods during the winter rest period. Limes, ggapefruit and shaddock are adapted to the humid warm tropical climate. Citrus trees make high demands on the water supply because of their transpiration throughout the entire year. Therefore, an intensive cultivation is usually associated with systems of irrigation. The minimum rainfall required is stated to be 1,200 to 1,300 mm. When the water supply is ensured, citrus will thrive on almost all soils which are sufficiently deep.

The majority of citrus species is propagated by grafting. Consequently, the problems associated with the stock resemble those connected with the apple. The stocks exert an influence not only

on the readiness to grow of the scion and its vigor but also on resistance to diseases and on quality. Breeding, selection and testing of stocks is an important task of citrus research.

A few botanical peculiarities of citrus species are of particular interest. The petioles are either slightly or more distinctly winged or non-winged. The twigs are either provided with thorns or they are smooth. From the ovary of the fragrant flowers, a berry-like fruit develops. The rind of the fruits is distinguished into two layers. The outer layer is called flavedo, it is the coloured layer of the mesocarp, and under favourable site conditions, carotinoids colour it yellow or orange. The whitish inner layer is called albedo which is somewhat spongy. The edible part of the fruit consists of segments which are filled with multi-cellular juice hoses. The seeds are embedded in these hoses; one seed sometimes contains several germs of which only one is fertilised, however (nucellar embryons). Either the fertilised one or the non-fertilised one will sprout. The harvest of fruits to be eated fresh is by hand and thus constitutes a great labour peak. Mechanised harvesting has only proved a success for commercial fruits so far.

The external and internal quality of the citrus fruits is essentially influenced by the temperatures and humid conditions during their development and maturing time. Although the inner quality cannot be derived from the external appearance of a fruit, the buyer will be guided by it and looks for a uniformly yellow or orange coloured fruit.

Oranges, beyond all doubt, are those citrus fruits which have the widest distribution and are well-known all the world over. They are native to South China. The globose to subglobose fruits have 10 to 13 segments and in the mature condition are light orange to dark red in colour. The edible pulp contains 30 to 50 per cent of juice, the taste should be sweet but acid aromatic. The best properties of the fruit to be eaten and the best colour have fruits from the subtropic climates. Oranges from

tropical regions are less tasty and frequently are of a poorly coloured appearance but their content of juice frequently is high. Well-known varieties are naval orange, shamouti (Jaffa), blood and semi-blood oranges (red colour of the rind and the pulp), Valencia late.

Mandarins, also known as tangerines, are weaker in growth than orange trees. The usually small, yellow to orange coloured fruits have a roundish shape. The rind can be easily detached and the flavour of the pulp is species-specific, two typical features of this citrus fruit. The segments can easily be removed.

Lemons usually have oblong fruits. Under suitable conditions, they can be harvested three times a year. Therefore, it is possible to market lemons throughout the year. In general, the fruits are ripe when the green rind shows a lustre.

Limes frequently are preferred over lemons by the connoisseur. There are sweet and acid limes but only the latter are economically of importance. The very flavoury acid limes have a thin rind, are very juicy and thrive particularly well in tropical regions.

The grapefruit is said to have developed from the great orange. The grapefruit is a typically globose citrus fruit with a bitter yellow rind and a highly flavoured sweet and somewhat acid juicy pulp. The bitter substance known as naringin contained in the grapefruit causes the characteristic taste of it. A citrus fruit closely related to the grapefruit is shaddock which is larger but differing especially in its loose rind.

For shipping, the citrus fruits are treated in special packing and ripening houses. When the ripe fruits still exhibit a green colour are subjected to a treatment by means of ethylene at a temperature of about 30 °C and 85 to 90 per cent of atmospheric humidity to remove the green colour. Special washing plants serve for the cleaning of the fruits to remove dirt, deposits of sooty mould, coccids and residue from spraying. Sometimes the fruits are subjected to a "beautifying" treatment (this must

be marked for identification). Waxing the fruits is a widely used method which produces a fine gloss on the rind and restores the natural wax layer which has been impaired by washing to its original condition. Protective agents for storage are also used. If, due to the application of these agents the rind is no longer edible, this fact must be marked for identification.

Banana (Musa spec.)

The banana plant has a soft herbaceous stalk growing up to 6 m high which is formed by the leaf sheaths. Hence, the banana plant is not a tree but a shrub. The diameter of the non-lignified herbaceous stalk is anything between 20 to 30 cm. The large leaf blades are more or less ripped laterally by the wind, a fact which is particularly obvious in older leaves. A distinction is made between the fruit bananas, which rank high in the world's fruit trade, and the cooking or flour bananas. The latter are eaten in the cooked, roasted or fried condition or prepared in another way. The world production of fruit bananas has been reported to be, in 1981, 39.9 mill. tons and that of cooking and flour bananas 22.4 mill. tons. Important producer countries of fruit bananas are (1981) brazil (6.7 mill. t), India (4.5 mill t), Ecuador (2.2 mill. t), Indonesia (1.6 mill. t), as well as Costa Rica, Honduras, Panama, Colombia, Thailand, the Philippines, and Venezuela each producing more than 1 mill. t. Cooking bananas are prdocued especially in Uganda (3.6 mill. t), Nigeria (2.3 mill. t), and Rwanda (2.1 mill. t).

Remarkable features of the banana are the facts that the fruits do not contain seeds and that the plant belongs to the monocotyledons. All of the seed-containing bananas (wild forms) are scarcely or not edible. The inflorescence of the bananas develops by the change of position of the vegetation point. It is located in an eye of the rhizome , at first only forms leaves, at a certain stage of the development starts with the formation of the inflorescence and pushes it upwards inside the herbaceous

stem. The flowers are arranged in the axils of conspicuously reddish-brown coloured bracts. When the bracts of the flower bud unroll, the banana fruits (fingers) arranged in double rows (hands) become visible in their initial size. They develop without fertilisation (parthenocarpy). The fruit is a three-cell berry. The whole infructescence is called bunch.

Until today, the bred varieties of bananas have not obtained any importance. The well-known export varieties (Cavendish group) and all other edible varieties of banana (more than 200) have developed with any influence exerted by man. They were found and utilised. The term "variety" is, thus, not justified because breeding efforts by man have not been the starting point. Since propagation by seeds is not possible, vegetative parts of the plant are used for reproduction. From the subterraneanly thickened rhizone (reduced stem), eyes arise from which suckers develop. When they have formed a sufficiently large daughter rhizome, they are removed from the parent plant and used as seedling for planting. Parts of the rhizome having one or two eyes are also used.

Important cultivation problems are moisture sufficient throughout the year (usually the ground is irrigated), fertile soils with a good water volume (water surplus caused by insufficient draining of gravitational water is not tolerated by the plant) and protection from wind. In intesnive cultivation, these requirements must be met because the banana plant requires large amounts of water and nutrients in order to produce the large plant mass and the fruit bunch having a weight of 30 to 40 kg. Another problem is the transport of the sensitive plants over greater distances. The bunches which are always harvested in the unripe state must be transported to the local markets or for export to the ports and then per ship overseas. Today, the bunches are divided into the individual hands (8 to 20 bananas attached together on their stem) in packing stattions of the plantations. The hands are washed and packed in cardboard boxes and partly in foil. For export, bunches of the same stage of maturi-

ty must be cut. From the harvest to the loading in special banana ships, not more than 36 hours should be allowed to elapse. A ship must be fully loaded within 3 days. On board, constant temperatures from 11 to 14 °C (depending on the variety) are required because the bananas must arrive in the green state in their countries of destination to ensure their capability of being transported and to prevent quick decay. In these countries, the are transported by rail to central ripening stations. At adequate temperatures, the fruits are ripened in these stations and then distributed to the retail trade. The production and the export of bananas call for expert knowledge and a detailed and precise organisation. Among other things, these reasons have led to the fact that production and export trade are closely associated and are controlled by a few monopoly countries.

Pineapple (Ananas comosus)

The pineapple plant is native to the region extending over the central and northern part of South America. Today, the pineapple is found throughout the tropical range and far up into the subtropics. On an international scale, this fruit is among those having the widest distribution. In 1981, the world's production amounted to 8.9 mill.tons. Important banana growing countries are Thailand (1,800,000 t), the Philippines (1,200,000 t), Brazil ((625,000 t), India (593,000 t), and Hawaii/USA (590,000 t).

The pineapple is a monocotyledon of the family of Bromeliaceae. It is a perennial herbecaeous plant with a stem about 20 cm in length. From this arise in a dense and rosette-like arrangement the leaves having a length between 60 and 120 cm and a width of 3 to 6 cm; they are rigid, spiny-margined and dark green. The drought-resistance of the pineapple is remarkable. I can survive dry spells for months; it requires, however, an annual rainfall of 1,000 to 1,500 mm to obtain good yields. The lower limit of precipitation are about 600 mm. The temperatures should be high and well balanced. Below 20 °C, a retardation of growth

takes place already. Although the plant will thrive best with full light incidence, the ripening fruits require a protection against solar radiation if the latter is too intense to avoid damage (straw or grass covering and the like). All species of pineapple are self-sterile and mostly seedless. Seeds will be developed when different varieties are grown side by side and pollen transmission is effected through the very small openings in the densely arranged petals. The inflorescence develops from the vegetation cone of the short stem in the centre of the rosette. By far more than one hundred individual flowers are arranged round about the peduncle. A berry develops from each flower. These berries ripen into a solid mass forming the well-known pineapple fruit; this shows that the pineapple is composed of many individual true fruits while the pineapple itself is a sorosis. For propagation, sprouts from the lower part of the stalk and from the leaf axils are used. The tuft on top of the pineapple fruit is also well suited for propagation. Depending on the age of the planting material, the first crop can be harvested after 12 to 24 months after planting. One and the same stand of pineapple plants can be utilised for harvesting three times only because the yields decline quickly (about 30 t of the first harvest will be followed by 20 t of the second crop and 10 to 15 t per hectare of the third crop).

The great number of varieties can be divided into the Cayenne group, the Queen group and the Spanish group. Some varieties are better suited for tinning (Cayenne) and other varieties for being eaten fresh (Queen). A large portion of the crop is eaten in the fresh condition in the producer countries or processed into pineapple preserves (slices, segments, pieces). The world's exports of fresh fruits of about 150,000 t are comparatively low.

Methods for the artificial initiation of flowering in pineapple have reached a high developmental stage. The possibility of

applying such methods has been discovered accidentally in the Azores when, 4 to 6 weeks after the use o fire developing heavy smoke for frost protection, an unexpected flowering took place. The active substance was discovered later, it is the ethylene contained in the smoke. Acetylene and propylene proved to be similarly effective. While in former times, and even still today, small pieces of carbide have been used together with water, placing them into the centre of the rosette of the plants (formation of acetylene), today growth-regulating substances are available which are easier in handling. Until now, ethylene emitting substances have proved to be best. This shows that it is possible, today, to cause pineapple to flower and develop fruits throughout the year provided a certain number of factors are taken into consideration in the pineapple-growing regions. This possibility of producing pineapple throughout the year is of particular importance to the tinning industry. Pineapple cultivation is an illustrative example of the possibilities offered to man for controlling biological processes.

Mango tree (Magnifera indica)

From its native region, the mountainous regions of India and Burma, the mango tree has advanced into almost all areas of the earth where, today, the mean monthly temperatures of the coldest month (the month of January on the northern hemisphere, the month of July on the southern hemisphere) does not fall below 15 ^{o}C. Hence, this is a plant which finds its most favourable conditions of growth in the tropical climate and still in the war subtropical region.

The wide distribution of the mango tree within the climatic range most suitable for it is due to its fruits which are among the most important fruits of the tropical countries. In countries of the temperate climatic region, fresh mango fruits either are not in the market or they are offered at high prices. This is due to the limited storage stability and poor capability of being

transported of the fruits. In overseas trade, air transport is usual for this reason. When the fruits are harvested carefully at the correct time and then stored at an atmospheric humidity of 85 to 90 per cent and temperatures between 5 and 10 °C, they can be kept fresh and edible for a period of up to 6 weeks. For transport, the fruits must be placed on a soft support in single layers.

Processed mangoes are of greater importance to international trade. They are on offer in tins as a sweet or seasoned compote in the form of slices, cubes or halves. Mango juice is a much desired product among the fruit juices. The flavour of the fruits is impaired, however, by any tinning process. A connoisseur will always give preference to a fresh mango.

The most important mango-growing country is India where in 1981 about 50 per cent of the world's area under this crop were found and about 8.5 mill. tons are harvested every year. Further important mongo-growing countries are Pakistan, Brazil, China, Egypt, Mali and Cuba. A distandvantage is the fact that the trees show a distinc yield alternance so that, alternately, a good yield is followed by a bad one. In the majority of countries, the harvest period is limited to about three months. Only in India where considerably differences in the climate exist, almost throughout the year, mango fruits are harvested.

The mango tree is a rapidly growing evergreen plant reaching a height of 20 m and having a dense, round and frequently widely branching top. It has alternate coriaceous leaves having a length of 12 to 15 cm and a width of 2 to 8 cm. The inflorescences in branching erminal panicles resemble those of the chestnut. There is a great number of varieties. The consistence of the ripe fruits resembles that of peaches. The size of the fruits, which are green, yellow-green, yellow or orange in the mature state, is between the size of plums and double the size of a fist depending on the variety. The large central stone has a flat-oval shape and a hard ligneous shell; the external fibrous layer

of the latter extends into the pulp, the numbre of fibres being different. For eating, varieties with a less fibrous pulp are preferred.

The pulp is very juicy, aromatic, and pleasently subacid and has a yellow or reddish colour. It contains much vitamin A and high amounts of vitamin C. The highly appreciated typical taste is not easily compared for description. It is somewhat suggestive of carrots and a very slight indistinct flavour of turpentine may also be involved. The taste is depending on a larger number of aromas and it may be said that it is well balanced. Mangoes are among the most delicious tropical fruits.

For breeding mangoes, seedlings are grown for grafting. There also are varieties which can be directly propagated by seeds on the basis of polyembryony. The first crops will be yielded in the 3rd to 4th year of growth. The trunk of old mango trees are widely used for the production of canoes which are hewn out of the mighty mango stems en bloc.

Papaya (Carica papaya)

The fast-growing plant is raised from seeds and develops a non-branched or only little branched shrub having a height of up to 8 m and a stalk which has a spongy tissue as a skeleton and is hollow more or less. The stalk ends in a tuft of long-petioled leaves which are palmeately 7-lobed. Shed leaves leave clearly visible stigmataon the stalk. The hieghest yield is obtained from papaya in the period from the 2nd to the 4th year. The flower biology of this plant is interesting. There are male flowers, female flowers and hermaphrodite flowers which occur separately on a plant. Male, female or hermaphrodite plants can only be identified at the time of flowering. For new plantations where hermaphrodite varieties are not involved, two to four plants are planted in each planting site of which, at the time of the first flowering, 90 per cent of the male plants are

removed. The remaining 10 per cent are necessary to ensure the fertilisation of the female flowers.

Papaya is a typical plant of the tropical climate region. It cannot tolerate any frost. Its limits of cultivation are between 32° of north and south latitude. Obviously, papaya is native to Central America.

The fruits are cylindrical or pear-shaped or tapering, 7 to 30 cm long and up to 9 kg in weight.
A large number of dark, peppercorn-like seeds are arranged inside the fruit. The highly perishable fruit remains externally green even in the fully mature condition. The pulp has a golden-yellow to orange-red colour and a soft consistence (comparable with very mature pumpkin). For raw eating the fruit, sugar and lemon juice is frequently added because the flavour of the fruit is less distinct. Papaya is also suited as a constituent of mixed fruit salad. Unripe fruits are boiled and used as vegetable together with a main dish. Due to the poor transport and storing properties of the fruits, they occupy an unimportant position in the world's fruit trade. The fruits are maturing almost continuously throughout the year. Per plant, 30 to 100 fruits can be expected. The yields per hectare are between 40 and 70 t.

In addition to the valuable fruits, the enzyme papain can be obtained from papaya. In pharmacy, it is used as a digestant agent (decomposition of protein). For the production of papain, the fruits are scratched. From these injuries in the peel of the fruits, a milky juice (latex) is excreted immediately.

Passion fruit or granadilla (Passiflora spec.)
This plant is native to the tropical and subtropical part of America, Asia and Australia. It is a relatively young cultivated plant. For the first time it was grown for sale in Australia in 1932. Today, the passion fruit is increasingly gaining in importance because very tasty fruit juices can be made of it.

The distimct aroma of the fruit juice is still clearly perceptible at a very high degree of dilution. The intensity of the flavour is three times that of the orange juice. Since the juice has a pleasant taste that differs largely from that of other fruit juices, the demand for passion fruit juice is on the increase in the world market.

The passion plant is a perennial, evergreen, gradually lignifying climbing plant which is fast-growing. The wonderful large flowers open at noon. Since it is an allogamous plant, i.e. a plant reproducing by cross-fertilisation, budding can be increased considerably by manual pollination. The fruits have a spherical to egg-like shape and reach a diameter of anything between 5 and 10 cm. The 3 to 6 mm thick external peel is very fragile. Inside the fruit contains a large number of small, dark-coloured seeds. They are embedded in a flavoury, slightly acid, yellowish, gelatin-like, juicy pulp from which the juice is obtained by pressing.

The passion plant is reproduced both by seeds and by cuttings. When seeds have to be used, controlled manual pollination is required because of the allogamy. If this is neglected, the seeds will grow into plants which will exhibit quite different properties. The young plants raised from seeds or cuttings are suitable for replanting when they have reached a height of 25 to 30 cm. The first fruits become mature after 9 to 12 months.

Since the passion plant is a climbing plant, espaliers are required. The kind of material to be used for them is depending on the given possibilities, on the one hand, and on the time of utilisation envisaged which may be anything between 8 and 10 years in the subtropics and between 5 and 6 years in the tropics. To facilitate the harvesting and cultivating operations, the espaliers usually have a height of not more than 2 m. The exuberant growth of the passion plant is regulated by adequate

measures of pruning associated with tying up the main shoots for intensive cultivation.

The ripe fruits have a dark violet or deep yellow colour. The colour of the peel is dependent on the species in question. Peak yields are about 350 dt/ha and frequently crops of only 60 to 150 dt/ha are harvested. The average yields are about 150 to 200 dt/ha. After washing, the fruits are pressed out by special machines in which the juice is separated from particles of the peel and seeds. The acid degree of the raw juice having a pH value of 3.0 is extremely low. Therefore, the raw sap in the non-processed is practically not drinkable. The intense yellow colour of the juice is effected by a high percentage of carotene contained in it.

Date palm (Phoenix dactilifera)

For the inhabitants of the arid regions of North Africa, of the Near East and parts of the Middle East, the fruits of the date palm are of considerable importance as a food. The great number of varieties are grouped in soft, semi-dry and dry varieties. For export, mainly some of the semi-dry varieties are of interest.

The main field of cultivation of the date palm extends from Morocco to Pakistan through the Afro-Asiatic dry zone; this species of palm is native to Pakistan. In the area of the present Iraq, the date palm was cultivated already 3,000 B.C. as can be proved. We should take it for granted, however, that date fruits were used as food and feeding stuff at much earlier times. More than three quarters of the world's production are produced in the Near East. In 1981, Egypt produced 428,000 t, Iraq 405,000 t, Pakistan 205,000 t, and Morocco 105,000 t. The most important exporting country is the Iraq (1981 = 155,000 t), i.e. 63.5 per cent of the world exports.

The date palm finds its optimum site conditions in arid regions with a high summer temperature and sunshine. Heavier rainfall in the course of the flowering period may prevent pollination. During the development of the fruits, rain may cause the fruits to burst. The date palm meets its water requirements by means of deep-reaching roots (down to 6 m) from the ground-water or from water of irrigation. The compatibility with salt of this plant is remarkable. It tolerates 1 to 1.5 per cent of salt in the soil solution and pH values of up to 8.0.

There are male and female date plants. For the reproduction of the female dates, shoots having an age of from 5 to 10 years are used which develop at the stem base of older female palms. Since antiquity it has been known that yields can be increased when hanging the twigs of male inflorescences into the female inflorescences (improved pollination). Today, it is common use to distribute the pollens, which are durable for a period of two to three months, by hand, by means of hand devices or machines at the flowering time. The annual alternating between high and low yields can be balanced to some extent by thinning the budding in years of intense fructification.

Date palms reach the full yield between the 20th and 30th year of their age. How long the full yield can be maintained is depending on the site and cultivation measures (maximum 50 to 60 years). During this time a date palm can produced 75 to 100 kg of fruits a year. On the norhtern hemisphere, the harvest takes place in the second half of the year. The crop is gathered in by people climbing the palms and carefully lowering the cut off infructescences or by means of technical equipment (hydraulically adjustable platforms, ladders). Maturity is indicated by a change in colour of the green fruits. Depending on the variety, they change to yellow-green, yellow, red or dark-brown.

Dates are eaten in the fresh condition and processed into jam or date syrup. The fruit botanically is a berry; a hard stone is embedded in the pulp. Depending on the extent to which starch

is transformed into sugar, the dates are "sweet" (juice dates) or dry starch dates (the latter are the "daily bred" of the desert inhabitants). In the dry state, dates are well durable.

Cashew nut (Anacardium occidentale)

In colloquial usage, nuts are defined as dry-shell fruits (e.g. hazel-nut) or parts of fruits (walnut, coconut) or seeds (Brazil nut).
Botanically, nuts are called dry indehiscent fruits. The most important species of nuts are cashew nuts, walnuts and almond.

The cashew tree is a typical tropical plant. It is native to that part of North-east Brazil where rainfall is rather limited. Throughout the world, more than 450,000 t of cashew nuts are produced annually. The highest production has India (190,000 t), then follow Brazil (85,000 t), Mozambique (75,000 t), Tanzania (72,280 t), and Kenia (15,000 t).

The increasing demand for cashew nuts and cashew nutshell oil have led to a marked rise of the cashew production. This expansion of production is also promoted by the relatively low site requirements and expenditures for planting and cultivation operations. The cashew tree finds favourable climatic conditions in summer rain regions of the tropics where precipitations amount to anything between 500 and 3,000 mm. The drought-resistance and low soil requirements of this tree ensure that it can still be grown in situations where other cultivated plants cannot be grown for economical reasons. For high yields, however, sufficient moisture and fertile soils are an essential precondition.

The fast-growing evergreen cashew trees branch immediately after the stem base so that usually only a short stem is present. The top of the tree reaches a wide extent with increasing age and can be up to 15 m in height and 12 m in diameter. The flowers

are arranged peripherally.The kidney-shaped fruit is attached to a fruit stalk which swells into a pear-shaped, pulpy, yellow or red sorosis having a length of 4 to 8 cm. In the soft, loose tissue of the so-called cashew apple on which the cashew nut is borne and in which a sweet-acid juice is contained which is drinkable in the raw state. The juice can also be sued for the production of juice, soft drinks, alcohol or vinegar. Mostly, the soroses are not utilised. One allows the mature fruits together with the soroses drop from the trees. When collecting them, the soroses are separated from the fruits; the soroses mostly are damaged (by insects, injuries due to the fall, dirt). The fruits consist of kernels (cotyledons) to the amount of 35 to 45 per cent and shells to the extent of 55 to 65 per cent. The latter have a honeycomb-shaped structure and, therefore, are very strong. The shells contain the slightly toxic cashew nutshell liquid. In the chemical industry, it can be manufactured into a number of different rpdocuts. One t of fruits yield about 200 kg of "nuts" and 180 kg of nutshell liquid which is also termed as oil.

In former times, and sometimes even today, the shells were opened manually. The low wages paid in India were the reason for the fact that the major part of the East African cashew production was exported to India for processing. To protect their skin against irritation by the nutshell oil, the workers applied a film of ashes to their hands and arms. Today, fully mechanised plants are available where the fruits are roasted (to extract the nutshell oil), broken, dried, sorted and vacuum-packed.

The cashew trees primarily reproduced by seeds produce their first budding after 4 to 5 years. More than 50 kg/tree can be harvested from the adult tree. The nuts are either eaten directly (salted) or they are used in the chocolate production. The substances contained in the nut include about 22 per cent of protein and 45 per cent of fat so that edible oil can also be produced.

III. 2.2.5. Luxury goods plants

Coffee (Coffea spec.)

Coffee is a drink that definitely is a luxury. It does not contain any nutrients or other vital substances (for example vitamins). The fact that it is widely distributed is based alone on the stimulating effect of the caffeine and its pleasant taste. Throughout the world (1981) about 5.8 mill. t of coffee are produced per year. Brazil ranks first; its production, however, has be subjected to considerable variations due to heavy damage by frost in the coffee plantations in the state of Paraná in 1975 (1975 = 1.3 mill. t, 1976 = 389,000 t, 1977 = 950,000 t, and 1981 = 1,878,000 t). Of this situation, advantage was taken to run up proces drastically for coffee in the world market. Further important producers are Colombia (808,000 t), Ivory Coast (350,000 t), and Mexico (217,000 t).

The genus Coffea comprises a greater number of species. Economically of importance are only Coffea arabica and Coffea canephora (Robusta). Arabica coffee, which yields 75 % of the world's production, is native to Ethiopia. Then, it was brought to the Arabian peninsula, to the area of the present Yemenitic Arab Republic. There, the cultivation of coffee reached a high level associated with a high quality, and since the export port bore the name of Mocha, the designation of Mocha coffee is closely related with Yemen, where the first coffee plantations were cultivated, and exists besides the name of Arabica coffee.

The Arabina coffee has the preferred taste. The larger amount of this coffee today is produced in America while in Africa the cultivation is focussed on Robusta. The latter has gained in importance for the production of the coffee that is immediately soluble in water and where no particular emphasis is placed on the better flavour present in the Arabian coffee. Robusta coffee is less fastidious and can produce better yields.

Arabian coffee is adapted to cooler temperatures and, therefore, thrives best at certain tropical altitudes (Tanzania, Colombia) or in the summer rain regions of the subtropics (Brazil). For the differentiation of the flower buds, a dry period (of 2 to 3 months) and high temperatures are required. Robusta coffee calls for higher average temperatures and, thus, can also be grown in the tropical lowlands.

Coffee is usually reproduced by seeds which, however, remain capable of germinating only for about two months. When the young plants have developed about six pairs of leaves, planting is started. The stocks of coffee are highly specialised. There are upright and laterally growing shoots; the laterally growing ones cannot produce upright shoots .For the purpose of facilitating harvest, the coffee shrubs are cut back to about 1 m after a period of 8 to 10 years. Other cutting methods are also known which, however, are more time-consuming.

The cherrylike fruits growing in clusters become cherry-coloured when mature (certain varieties become yellow). They are stone fruits usually containing two seeds. Sometimes, monoseeded (round seeds) or multiple-seeded fruits occur. The fruit consists of a tough outer skin, the juicy acid-sweet pulp and the horny skin covering each seed. The seed is directly covered by a thin silvery seed skin (silver skin). The chief mass of the seed consists of the folded endosperm. High quality coffee can only be obtained from mature fruits. Since ripening takes an irregular course, it is advisable to pick the fruits at intervals. After harvesting, the pulp is squeezed off in a wet process and the remainder dissolved in a short fermentation process. In the dry process, the whole fruits are dried and then the green coffee ready for being roasted is obtained by peeling (removing the horny and silvery skins). The content of caffeine may reach 2.5 per cent. Coffee containing more than 2 per cent of caffeine is called rich in caffeine and that containing less than 0.2 per cent is called poor in caffeine.

Tea (Camellia sinensis)

Today, tea is among those beverages which found the widest distribution and, in contrast to coffee and cocoa, large quantities were already consumed in the producer countries in early times. Its original habitat cannot be stated definitely and apparently it is situated in the south-east Asian highlands (highland regions of South-west China, North Burma and North-east India). Until today, Asia supplies the major portion of the worlds production. Smaller cultivation centres are in East Africa and South America (Argentina). The world's production are 1.8 mill. t of marketable tea. Among the producer countries, India ranks first producing 565,000 t. Then follow China (354,000 t), Sri Lanka (210,000 t), the USSR (135,000 t), and Japan (103,000 t).

When not cut back, the evergreen tea plant develops into a tree having a height of up to 15 m. Since, however, only young leaves, maximum up to the 4th leaf from the tip of the shoot, contain the required substances in adequate quantites, shrubs having a maximum height of 1.5 m are more favourable for the harvest. In addition, the cutting back of shrubs every 3 to 4 years, causes the development of a great number of fresh shoots. These are harvested every 7 to 10 days in humid-warm climates. Flowering and the formation of seeds are undesired because this will impair the production of new shoots. For the production of seeds, special tea trees are cultivated. In the fully mature condition, the seeds have the best germination capacity. Therefore, thay are allowed to drop from the trees and then they are gathered in. In modern tea cultivation reproduction by sets is exclusively used otherwise special plant breeding gardens have to be provided for seed production with selected cross-breeding partners. Since tea is an allogamous plant, the use of seeds gathered at random will lead to quite different descendants (segregation).

Tea cultivation in the Soviet Union is of particular interest where the tea plant reaches its northernmost boundary of cultivation at 45° north latitude in Transcaucasia (Georgian S.S.R.). Soviet breeders have already succeeded in breeding varieties which are highly resistant to frosts. This shows that the tea shrub can be grown in the tropics at altitudes of about 2,000 m (Sri Lanka), in the tropical lowlands, in the subtropics and in warm-temperate regions. The best qualities are obtained from tropical altitudes, the highest yields from tropical lowlands. Tea of a minor quality is used as an admixture to the finished product. The most favourable growing sites have a high atmospheric humidity, ample and well distributed rainfall (2,000to 3,000 mm) and an adequately water-bearing soil. It is remarkable that the tea plant tolerates extremely acid soil conditions (pH up to 2.8).

In countries with a large labour force and cultivation on sloping ground or mountainous regions, tea is harvested manually. In the Soviet Union complete harvesters are available which necessitate the growing of tea plants in hedges with a specified distance between the hedge rows. In the climatic boundary regions for tea growing in the Soviet Union, harvesting is only possible in summer during the shooting time of the plants.

The popularity of the beverage prepared from the leaves of the tea shrub is due to its delicately bitter taste and pleasant flavour associated with a stimulating effect (the caffeine content of the leaves is between 3 per cent in the 3rd leaf and almost 5 per cent in the unfolding top buds while the catechin content is between 17 and 27 per cent, respectively). Tea growing is advantageous for the developing countries because the tea leaves must be processed on the spot so that the finished product is exported. For processing, the fresh leaves are allowed to wilt slightly, mechanically formed (usually rolled) by different machines and then subjected to fermentation with subsequent drying and sorting. Gree tea is only heated, rolled

and dried after harvesting, that is, it is not subjected to a fermentation process. The average yield is about 1,100 kg/ha, peak yields amounted to 9,000 kg/ha of marketable tea.

Cacao (Theobroma cacao)

Foods or plant products for food production which are consumed primarily because of their stimulating effect are usually called luxuries. Frequently, they have no or only an insignificant nutritive value. Sometimes, they contain alkaloids which exercise a stimulating effect on the nervous system when consumed in small quantities, as it is the case with cocoa, coffee, tea and tobacco, or they improve the taste and are appetising.

Cacao is a typical example of this fact and shows that, in the plant kingdom, clear and distinctive classifications are frequently possible only to a limited extent. The seeds of the cacao tree contain certain alkaloids (0.9 to maximum 2.5 per cent of theobromine and caffeine), on the one hand, and about 50 per cent of fat and 15 per cent of protein, on the other. This shows that cocoa should be considered both a luxury good and a foodstuff.

As a typical plant of the humid tropics, cacao is native to South America within the region of the Amazon and Orinoco. There, it is found as undergrowth in the tropical rain forest. Its present areas of cultivation (South America, West Africa) do not go across 20° north or south latitude. In the world's production of 1.6 mill. t (1981), the following countries have taken part: Ivory Coast with 430,000 t, Brazil with 345,000 t, Ghana with 230,000 t, and Nigeria with 160,000 t.

For thriving well, the cacao tree requires annual mean temperatures of anything between 24 and 28 °C with variations which are as small as possible in the course of the day and of the year, a high atmospheric humidity, and well distributed rainfall of 1,500 mm throughout the year.

A few botanical features of this plant are of particular interest. At first, a shoot is growing upright which, at a height of 0.75 to 1.50 m, branches into 3 to 5 twigs while shedding its terminating bud. This first "story" is followed by further stories brought about by the development of new upright shoots arising from below the branching points, and these shoots branch out again after a growth in height of further 0.75 to 1.50 m. In plantations, the height of growth usually is limited to one or two stories. Flowers only arise from the stem and thick branches. The fruits, botanically they are berries, have a length of 10 to 20 cm, a thickness of 5 to 10 cm and contain up to 50 seeds (which frequently are wrongly called cocoa bean or cacao bean). The mature fruits are not shed from the trunk or the branches because a separating tissue is not formed. Since cacao is subjected to allogamy, seeds of a high quality must be produced in special seed breeding gardens. In intensive cacao cultivation, cuttings are primarily used. When preparing cuttings, care must be taken because cuttings from the lateral branches develop shrub-like plants. Upright plants call for cuttings from upright shoots.

After planting the plants raised in nurseries, usually by means of plastic bags, the first fruits can be expected after 3 to 4 years. The mature fruits are broken open and the seeds, which are surrounded by a whitish pulp, are subjected to a fermentation process in wooden boxes of several days. Subsequently, the water content must be reduced to about 5 to 6 per cent in order to ensure good storage and transport properties.

In former times, the cacao seeds were used as a currency by Red Indian tribes, this means that only rich strata were in a position to consume cacao. In the present cacao cultivating countries, in principle nothing has changed in this respect. Cacao products, which usually are imported from Europe or North America at high prices, are very expensive. For this reason, they have remained to be a luxury.

III. 2.2.6. Fibre plants

Cotton (Gossypium spec.)

Cotton is a soft fibrous substance that clothes the seeds of various plants of the genus Gossypium. The plants are annual or perennial and have a shrub-like appearance.
Every year, more than 15 million tons of cotton (without seeds) are produced on by far more than 33 million hectares. This clearly shows that cotton is the most important fibre plant of the world.

Important producer countries are the USA (3.4 mill. t), China (3.0 mill. t), the Soviet Union (2.7 mill. t) and India (1.3 mill t).
These figures indicate the yields of pure cotton. Frequently, it is not known that, of the total crop (that is the raw cotton), two thirds are seeds and only one third fibres. The seeds contain, among other things, 18 to 24 % of oil and 16 to 20 % of protein. By warm pressing, a valuable oil is obtained from the seeds which, after purification, is scentless and colourless and can be used as an edible oil and for industrial purposes. The oil press cake contains more than 40 % of raw protein and about 20 % of N-free extracted substances.

Probably, the cotton is native to Africa. Four different species are cultivated. Although utilisation for several years is possible, the annual crop is dominating in modern cultivation. The plants develop a tap-root penetrating down to 3 m into the soil. Leaves and stalks usually are densely haired. The large flowers are white, light yellow to dark yellow or purple in colour. The fruit is a capsule of an oblong pointed or round shape that bursts open when ripe. The 4 cells of the capsule contain the about 1.5 cm long and 0.5 cm thick seeds. The outer layer of the seed shell, the epidermis, carries the fibres. The development of the fibres is effected independently of fertilisation. A distinction has to be made between the long fibres, the lint, and the short

fibres which adhere to the seeds, the linters. The originally round fibres of the lint fall together forming a band when ripening while the edges are slightly rolled up. Further, the fibre in the ripe and dry condition shows a distinct spiral twist which is the decisive factor for the good spinnability of the cotton fibre. The most important quality feature of cotton is the fibre length, the so-called staple (below 2.5 cm is a short staple, from 2.5 to 3.5 cm is a medium-size staple, over 3.5 cm is a long staple).

Cotton is a plant that loves high temperatures. For seeding, the soil temperature should be at least 18 °C (optimum 35 °C). During the growth period temperatures of about 25 °C are preferred. Since cotton is highly sensitive to frost, successful cultivation calls for a period of at least 200 frost-free days. Much sunshine favours flowering and budding. That is why very good yields are achieved in arid regions with irrigation (the USSR, Egypt). Seeding is effected by manual labour or by means of drilling machines. For drilling, the fuzz on the seeds must be removed mechanically or chemically otherwise the seeds will adhere to each other and fail to pass through the drilling machine. When ripening, cotton should not be exposed to rain because the latter will impair the quality of the fibre when the capsules burst open. High wind will cause losses due to the blowing away of ripe fibres from the capsules.
Harvesting is effected manually or with the help of machines.

On an average, the world yields of raw cotton are about 11 dt/ha. Under favourable conditions, up to 50 dt/ha can be achieved. For the removal of the fibres from the seeds, ginning machines or gins are used. Usually the tool of these machines is a saw-blade-like device which pulls the long fibres from the seeds. Damage may occur in this operation. For high-quality cotton having a long staple, the machines are provided with rolls of leather and depressions cut into them.

Fibre agaves

Of the more than one hundred species of agaves, which are native to the tropics and subtropics of America, only a few have an economical importance to fibre production. Sisal (Agave sisalana) only has reached cultivation throughout the world. Local importance have gained Henequen (Mexico, Cuba) and Cantala (the Philippines). The fibres obtained from the leaves of the agaves belong to the so-called hard fibres which, in contrast to the soft fibres (cotton, hemp, flax, ramie, and jute), can only be spun into coarse threads. Of the latter, ropes and coarse bags as well as brushes can be produced.

After cotton, jute and kenaf, sisal ranks fourth among the fibre plants yielding an annual crop of about 459,000 t. The most important countries of production and exporting this fibre plant are Tanzania, Brazil, Angola, Kenya, Colombia, Madagascar and Moçambique. Due to the increasing proportion of synthetic fibres the world's demand for agave fibres remains almost constant. The greatest advance was made by sisal cultivation with the introduction of the cereal binder and the threshing machine. Sisal yarn proved to be particularly suitable for binding sheaves and straw. With the wide-spread distribution of the combine harvester and modern harvesting technologies, the demand for binding yarn declined considerably.

The first large area for the cultivation of sisal developed in Mexico in the peninsula of Yucatan in the middle of the last century. The name of sisal was derived from the port of Yucatan from where fibres were exported for the first time. The first 62 sisal plants arrived in East Africa (Tanzania) from the American continent in 1893.

Sisal is a perennial plant which, depending on the site conditions, develops a huge flower stalk having a length of 5 to 7 m after 6 to 15 years and then dies. The majority of flowers

is shed. In the scar left by the fallen flower, numerous small sisal plants grow (brood bud bulblet, bulbil) which are dropped at a later time (1,000 to 4,000 per inflorescence). Planted in nurseries, the plantlets are sufficiently large (25 to 40 cm) after 12 to 18 months so that they can be planted in the production fields (double rows). The leaves having a length of up to 2 m form a large leaf rosette. Sisal is among the succulent plants, hence, it can endure prolonged periods of drought. For high yields, however, annual rainfall between 1,000 to 1,300 mm and temperatures over 25 °C are required.

Harvesting usually begins after 2 to 3 years from the date of planting, especially when the plants show about 100 leaves.

Harvesting takes place one or two times a year, and 18 to 20 leaves are left on each plant. The leaves are cut manually. The leaves are bunched together (about 60 t/ha) and transported to the rasping machines by light railway, lorries or tractors. The fibres are today removed by means of machines everywhere; in these machines, a rotating drum provided with blunt metal strips squeezes and beats the leaves. Apart from the fibres, all of the other tissue is reduced to so small pieces that it can be washed away by water (about 40,000 l of water are required per hour). The fibres are dried in sunshine or by means of hot air. Besides long fibres (more than 90 cm), short fibres are also obtained (about 10 %) which are used as upholstering material, mats and strips of carpet as well as for the production of paper and construction slabs. The best yields are about 2.8 t of fibres/ha/year, frequently hardly more than 1 t is achieved.

III.2.2.7. Caoutchouc

Caoutchouc is not a plant but a high-molecular hydrocarbon which is contained in the latex of many plants. In the age of the rapid

consumption of the hydrocarbon resources of the world (coal, petroleum), caoutchouch is increasingly gaining in importance. Without environmental pollution and with a low input of energy (fertilisers, plant protection agents, machines, etc.), certain plants continuously produce hydrocarbons. At present, the tyre industry is the greatest consumer of caoutchouc . In laboratories it has already been possible, to produce petrol of caoutchouc.

Para rubber tree

More than 90 per cent of the world's crop of caoutchouc (also called rubber) is won today from the para rubber tree (Hevea brasiliensis). In 1981, about 3.8 mill. tons were produced. The production of synthetic caoutchouc from crude petroleum was 8.8 mill. tons in the same year. Natural caoutchouc and synthetic caoutchouc cannt replace each other in any case. The most important countries producing caoutchouc of the natural type are Malaysia with 1.6 mill. t, Indonesia with 0.9 mill. t, Thailand with 0.5 mill. t, India and Sri Lanka with 0.15 mill.t each. Brazil is the native country of the Hevea tree; it produces only 28,000 t/year. The para caoutchouc tree is native to the Amazon region. At first caoutchouc was won from wild-growing trees. The demand for caoutchouc rapidly increased after the invention of pneumatic tyres for motor-cars in 1895 by Dunlop. The wild stands of Hevea trees no longer sufficed for meeting the demand. First plantations were developed in East Asia after, in 1876, about 70,000 Hevea seeds were brought from Brazil to England into a botanical garden (Kew Gardens). Since Hevea is capable of germinating for a short time only, only 3,000 young plants were obtained from the 70,000 seeds. They were sent to botanical gardens in East Asia. Only when the director of the botanical gardens in Singapur discovered the possibility of a continuous latex winning by cutting off thin bark strips (tapping), the arrangement of plantations had become economically sensible. The first caoutchouc from plantations was marketed in 1907.

The Hevea tree is a plant of the tropical rain forest. Its cultivation is limited by 15° to the north of and 10° to the south of

the equator. The average temperature should be about 28 °C and the raimfall amount to 2,000 to 4,000 mm. Hevea is a tree having a height of up to 30 m and a tap-root over 4 m in length. Latex is in a tubular system in the bark. In latex, caoutchouc is found in the form of small balls. For reproduction, seedlings are grafted. After 5 to 7 years, the young trees have reached a circumference of 45 to 50 cm at a height of 1 m and can be tapped. Special knives are used for cutting by means of which the bark is cut deeply but the cambium must not be injured otherwise the bark will not be renewed. The cut is oblique running from the left on top to the right downwards round half of the stem (this is the standard method but there is a number of other methods, too). Tapping should be performed very early in the morning. Latex is excreted immediately after cutting. It is conducted through a small conduit into a collecting vessel. For each tapping cut, not more than 1.5 mm of bark must be removed. After about 5 years, one half of the trunk has been tapped down closely to the ground. Then the other half of the trunk is used. Each half of the trunk is tapped twice. Tapping for a prolonged period of time is possible but it will lead to considerably declining yields. Therefore, the Hevea trees are removed after 25 to 30 years and replaced by new plantations. Acids (usually formic acid) are added to the collected latex. Consequently, the latex will coagulate and, thus, can be processed into different types of raw products.

Today, top yields are more than 3,000 kg/ha, frequently, however, not more than 1,000 kg/ha and sometimes even only 400 to 500 kg/ha will be achieved.

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(204) Ag 652/024/83