RUBBER TREE SEED PRODUCTION

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Importance of the Crop

(2) Rubber tree is an important crop native to the Amazon region (7°N a 15°S) comprising areas from Brazil, Bolivia, Colombia, Peru, Venezuela, Ecuador and Surinam (formerly Dutch Guyana). Currently, it is cultivated in many regions, e.g. from 24°N in China to 25°S in Sao Paulo state, Brazil. The crop's primary product is high quality latex with a high rubber content widely used in the tire and other essential products industries.

Thailand (35%), Indonesia (23%), Malaysia (12%), India (9%), and China (7%) are the world's largest natural rubber producers. The main world importers are China (18% of total), United States (13%) and Japan (10%).

(3) Brazil is currently the ninth world producer with an estimate of 115,000 hectares in 2003 (1.5% of world total). Despite several challenges, the rubber tree crop is economically important in Brazil which still imports 60% of the total country consumption.

One of the primary advantages of this crop is its perennial plant growth habit that allows continuing economic exploitation for many year. In addition, this species exhibits excellent performance as a component of production systems in combination with annual and perennial species such as maize, field bean, rice, coffee, cocoa, pineapple, oil palm and others. (4) The "partner" crop such as coffee can use these cultural practice benefits for longer periods because the rubber crop possesses a longer life cycle.

(5) Rubber tree is a perennial dicot in the E*uphorbiaceae* family and the genus *Hevea* that includes 11 species. But, *Hevea brasiliensis*, a native from Brazil, possesses the highest yield potential and genetic variability.

The most important approach to improving productivity was due to research programs from Asian countries that emphasized improvements in rubber tree propagation. The development of grafting techniques led to efficient plant selection procedures for more productive clones used in seedling formation compared to previous direct sowing techniques.

Direct sowing is not recommended because crop development is delayed in comparison to crops established from grafted transplanted seedlings. In addition, direct sowing plants have greater variability in vegetative growth, maturation, disease tolerance and other important aspects of crop performance including plant longevity.

(6) Plant Development

(7) Rubber tree seeds complete germination 10-15 days after sowing and produce hypogeal seedlings. Vegetative growth is vigorous and the adult plant is a tree 25.0 m to 40.0 m high. The primary tap-root is 5.0-10.0 m long and lateral roots usually reach 6.0 m to 9.0 m in lateral growth. Leaves are alternate and trifoliate.

(8) Flowers are monoecious and are found in raceme inflorescences. Flowering and subsequent seed production show wide annual variations in quantity and quality as a result of heavy rains and intense winds that may increase disease pressures causing young fruits to shed or abort prematurely. Flowering usually occurs from August to October in the spring in the Brazilian southeast. Flowering is also negatively affected by water deficits. As a consequence, possible variations in crop performance during the flowering period permit an estimate of crop yield potential.

(9) Fruit development continues during the warm, rainy season which occurs during the Brazilian summer. The mature fruit is a dehiscent capsule usually containing three seeds. The opening of the dry fruits occurs during late summer.

(10) Rubber tree seeds possess a brilliant spotted coat showing a prominent caruncle and usually are globate in shape. Significant seed production starts four years after crop establishment and mature seeds are shed for approximately five months after flowering.

(11) Climate Conditions

Temperature and relative humidity are the most important climatic conditions affecting plant developmental stages, latex production and seed yield. Regions with mean annual temperature lower than 20°C and high humidity are not optimum for rubber tree establishment because disease pressures are intense. Temperatures from 27°C to 30°C are the most favorable for rubber tree growth.

Latex Extraction

Latex extraction by "bleeding" is possible from the sixth year after crop establishment and proceeds for 25 to 30 years. Stem panel openings are recommended after 50% of the plant population has a minimum stem diameter of 45 cm at 1.5 m high on the tree.

(12) Plant longevity is affected by genotype, climate and crop management. (13) After each "bleeding", growth stimulators such as ethylene are applied to induce or favor stem cortex recovery and latex production.

(14) **Seedling Production**

Different approaches are available for producing rubber tree seedlings. Initially, it was common to use seeds produced in native areas. However, these materials were lower in quality and negatively affected crop growth and yield.

As a consequence, from 1980 to 1990, an initiative was established to promote high quality seed production in Brazil which increased cultivated rubber tree areas. This initiative also became focused on seedling production to obtain rootstocks and stalks for grafting that further improved crop productivity.

It is well known that high quality seeds are essential to produce vigorous rubber tree seedlings. In addition, the selection and production of clones adapted to different regions and possessing high performance potential contribute to greater crop yields. Rootstocks from seeds of hybrid cultivars are usually more vigorous than those from seeds collected in native areas.

Rubber tree seedling production often involves rootstock growth in nurseries, stalk formation and grafting operations. Production systems to attain these objectives can be accomplished in different ways.

(15) a) *Rootstock formation*

First, seeds are germinated to obtain small seedlings known as "spider paw" that are transferred to the nursery (16) or to plastic bags filled with artificial substrate.

The following photographs (17), (18), (19), and (20) show well-developed seedlings at the proper growth stage to be transferred to the nursery.

(21) b) *Clonal gardens*

There are different clones to establish rubber tree crops. The selection of the most appropriate clone depends on the region and characteristics desired by producers.

(22) Clonal gardens have the principal objective of obtaining plant buds for grafting using the same technology adopted for commercial seedling production. Those gardens have an approximate 5-year longevity with an objective to obtain "brown stalk" buds and a 12-year longevity for obtaining "green stalk" buds.

c) *Grafting*

(23) The selection of the best material for grafting is essential since vigorous buds affect rubber yield and rootstock development. (24) "Green stalk" buds are preferred because of their success in grafting, earliness of bud formation and longevity in the clonal garden.

(25) Vigorous seedlings are essential for adequate crop establishment, productivity and longevity.

(26) Seed Production

Grafted seedlings are transplanted to the field after sufficient rainfall or on cloudy days in 7.0 m - 8.0 m rows with 2.5 m – 3.0 m plant spacing to obtain an optimum population of approximately 500 plants/ha. The recommended hole size is at least 0.4x0.4x0.5 m. It is common to replant 20% of the seedlings to obtain the correct plant population.

Soil fertility is closely related to crop yield and proper NPK and other essential mineral elements must be provided. Pest control is also necessary and *Erinnys ello*, a worm called Mandorova is the most common insect attacking rubber tree leaves during leaf exchanging, flowering and fruit development periods.

Foliar diseases are not common in regions with moderate relative humidity such as in the Brazilian southeast, except for coastal locations. The incidence of the fungus *Oidium hevea* is detrimental to seed production.

Seed Harvest

Mature seeds are shed from dehiscent fruits to the soil. As a consequence, the area must be cleaned before seed collection to avoid picking up old seeds because rubber tree seeds are shot-lived, recalcitrant seeds. It is recommended that harvest occurs as soon as possible after shedding to prevent seed deterioration. Normal seed production yields vary from 70 to 500 kg/ha/year.

(27) In the Brazilian southeast, seeds are commonly harvested from February to April following weed control and "old" seed removal from the forest floor. Daily harvests

are strongly recommended, but when this is not possible, harvest intervals should not be longer than two days to avoid excessive seed exposure to unfavorable environments. Immediately after each harvest, seeds are packaged in plastic bags for storage.

(28) The Recalcitrant Behavior

The term recalcitrance refers to seeds that undergo no maturation drying as the final stage of development, tolerate very little post-shedding desiccation and are often chilling-sensitive. In contrast, orthodox seeds are shed from the parent plant at low moisture contents and their storability is favored by seed drying and decreases in temperature.

Species that produce recalcitrant seeds have adopted a reproductive strategy in which relatively large-sized seeds do not undergo drastic maturation drying as the final stage of development and usually do not exhibit a latent after-ripening period. These seeds are normally shed at regular intervals in humid environments at relatively high moisture content, usually greater than 30% on a fresh weight basis, and germinate almost immediately. Among the recalcitrant species, most are produced in the tropics, including several of economic importance such as mango, avocado, cocoa, coconut, rubber tree, guarana, oak tree, loquat, etc.

(29) The development pattern of orthodox seeds consists of a period of cell division, early expansion and morphogenesis followed by a significant increase in dry weight, and a third phase of rapid desiccation until hygroscopic equilibrium with the surrounding environment is achieved. In contrast, a common feature of recalcitrant seed development is the absence of rapid drying phase after maximum dry weight is attained. These seeds are shed or harvested at relatively high moisture content as shown in this Figure.

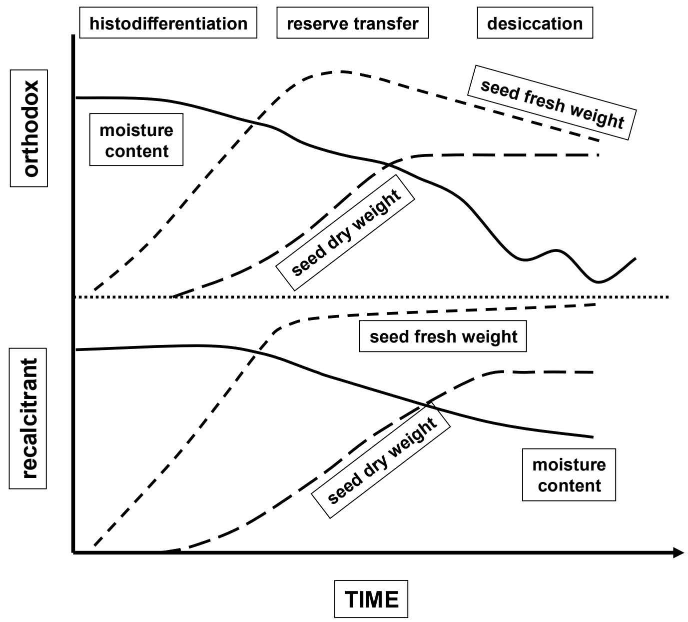

Figure. Relationship between seed fresh weight, dry weight and moisture content during the development of orthodox and recalcitrant seeds (Adapted from Berjak & Pammenter, 2000).

(30) Differences in the tolerance of recalcitrant species to water loss have been demonstrated over time. In this regard, there is a continuum of desiccation tolerance across species, varying from orthodox through less recalcitrant to highly recalcitrant as shown in Table 1. Where they fall on this scale may relate, in part, to the habitat to which they are adapted.

The less recalcitrant seeds can withstand more water being lost before viability is lost. In addition, the initial germination which continues despite the absence of additional water, usually proceeds very slowly. Thus, if not dehydrated to great extremes, these seeds can remain viable for fairy long periods. Those species are likely to have a subtropical habitat and, in some cases, a temperate distribution includes *Quercus sp.* and *Araucaria sp*.

Moderately recalcitrant species, for example *Theobroma cacao* or cocoa and *Hevea brasiliensis* or rubber tree do not tolerate as much water loss and germinate slightly faster than species in the previous category. However, in the absence of additional water, germination is sufficiently slow enough to maintain viability for several weeks if the moisture content is kept high. These species usually are found in the tropics.

In highly recalcitrant seeds, germination starts immediately and continues very rapidly, even in the absence of additional water. They can withstand very little water loss and, for this reason, these seeds reach the point where water becomes limiting and viability in storage is rapidly lost. Such seeds are shed into tropical forests or wetlands where sufficient water is available for continued germination throughout the year such as for *Avicennia marina* or *Syzygum sp.*

As a result, according to the scientific literature, it is suggested that seed species should not be labeled as orthodox or recalcitrant since a relatively wide variation is found in seed behavior with respect to desiccation and low temperature tolerances.

Table 1. The continuum proposed to account for varying degrees of recalcitrance (Farrant et al., 1988).

Types of Recalcitrance		
Minimum	**Moderate**	**High**
Fair amount of water loss tolerated	**Moderate account of water loss tolerated**	**Little water loss tolerated**
Germination slow in absence of additional water	**Moderate germination rate in absence of additional water**	**Fast germination in absence of additional water**
Lower temperature tolerated	**Most species are temperature sensitive**	**Most species temperature sensitive**
Temperate/tropical distribution	**Tropical distribution**	**Inhabit tropical forests and wetlands.**
Ex.: *Quercus*, *Araucária*, *Podocarpus*	**Ex.: *Theobroma*, *Hevea***	**Ex.: *Avicennia marina, Syzygum sp.***

Seed Storage

(31) Rubber seeds usually do not tolerate water loss below 35% on a fresh weight basis. The high seed lipid content also significantly contributes to rapid decreases in viability after harvest and rapidly reduces seed life span. When seeds will be immediately planted after harvest, they can be packed in permeable cotton bags and stored for short periods.

Seeds high in initial physiological potential and adequate moisture content (35%, fresh weight basis) exhibit high storability. However, when stored at moisture contents below 30%, viability is lost quicly, especially when exposed to low temperatures.

In contrast, if seed storage for periods up to six months is planned, they can be packed in plastic bags (65 cm long x 45 cm wide x 0.5 to 0.7 thick). Seeds are packed as soon as they are harvested and the bag volume should not be filled beyond 2/3 of its capacity (approximately 5 kg of seeds). The bags must be carefully closed since maintaining an empty space in the upper third of the bag where it is perforated with six holes, 1 mm diameter to allow gas exchange and keep the seeds at an adequate moisture content. The bags are placed in a vertical position throughout the storage period.

(32) Several other factors affect seed performance during storage besides moisture content and temperature. In general, storage potential is closely related to initial seed viability and vigor. This was demonstrated many times such as the results of Cicero et al. (1986) showed in Table 2. Seeds with 88% initial germination had greater storability when kept in a laboratory environment which maintained high seed moisture content. In addition, seed storage at low temperature with a Captan treatment rapidly deteriorated.

(33) Recalcitrant seeds are prone to storage microorganisms such as *Aspergillus* and *Penicillium* species that usually contribute to increased seed deterioration. However, fungicide treatment failed to provide seed protection during storage against these mircroorganisms as seen in table 3.

(34) In contrast, data in Table 4 show the effects of packaging material on seed conservation during storage. Plastic bags which are resistant to moisture movement between seeds and their surrounding environment maintained the highest germination for rubber tree seeds.

Table 2. Seedling emergence (%) from rubber tree seeds (35% m.c.) with or without fungicide treatment and stored n plastic bags placed in three different environments (Cicero et al., 1986).

Environments	Treatm.	Storage period (days)					
		0	64	127	187	249	510
Cold chamber (10°C/80% RH)	T1(‡)	66	70	11	10	01	00
	T2	88	76	19	12	04	01
Dry chamber (22°C/35% RH)	T1	66	77	44	34	30	10
	T2	88	82	60	42	27	17
Laboratory	T1	66	85	59	46	24	15
	T2	88	80	68	61	34	15

(‡) T1 =: seeds treated with 0.2% Captan; T2 = control

Table 3. Seedling emergence (%) from rubber tree seeds (24.8% m.c.) with or without fungicide treatment and stored in plastic bags placed In three different environments (Cicero et al., 1986).

Environments	Treatm.	Storage period (days)				
		0	70	145	204	285
Cold chamber (10°C/80% RH)	T1(‡)	66	08	01	05	03
	T2	88	12	08	02	01
Dry chamber (22°C/35% RH)	T1	66	23	05	06	01
	T2	88	27	10	04	04
Laboratory	T1	66	32	11	05	03
	T2	88	33	15	09	03

(‡) T1: seeds treated with 0.1% Benomyl; T2: control

Tabela 4. Germination (%) of rubber tree seeds stored in two types of packing material in the laboratory and in cold chamber at 10°C (Pereira, 1980).

Packing material / environment	Storage period (days)						
	0	30	60	90	120	135	150
Plastic / laboratory	**52**	**56**	**77**	**63**	**62**	**64**	**23**
Plastic / 10°C	**52**	**22**	**36**	**18**	**15**	**08**	**12**
Multiwall paper/ laboratory	**52**	**00**	**00**	**00**	**00**	**00**	**00**
Multiwall paper / 10°C	**52**	**00**	**00**	**00**	**00**	**00**	**00**

Seed Physiological Quality Assessment

(35) Assessment of rubber tree seed physiological quality is determined by germination and tetrazolium tests. Germination is conducted in large plastic boxes filled with sterilized, sieved sand moistened to 70% water holding capacity at $25^{o}C$ to $30^{o}C$. This species produces hypogeal seedlings and germination interpretations are performed at 15 and 30 days after sowing.

(36) To perform the tetrazolium test, seeds are conditioned between moistened paper towels for six hours at $30^{o}C$ to attain at least 24% moisture content. The teguments are then removed, seeds cut longitudinally and placed in a 0.5% TZ solution at $40^{o}C$ for 6 h. Following tissue color development, seeds are individually examined and separated into viable and non-viable categories based on the presence or absence of red-formazan color in vital areas.

(37) Conclusion

The production of rubber tree seeds will continue to increase as an important activity in Brazil since the worldwide and local demand for natural latex industrialized products continues to increase. As shown, rubber crop yields have a close relationship with high quality grafted seedlings whose formation directly depends on optimized seed production and quality control programs as reported here.