# The Interest in Seed Studies

*Luiz Fernando Gouvêa Labouriau*

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## 1. THE ROLE OF SEEDS IN HUMAN LIFE

Seeds are important for human life first of all because the genus *Homo* evolved at a geological time when the majority of the Earth's vegetation had been overtaken by phanerogamous plants. It is not surprising, therefore, that most vegetables utilized by humans belonged to this group of seed-plants. The task of identifying useful plants and determining which were edible or toxic, which could provide fibers, tannins, and dyes, which were medicinal and hallucinogenic, must have taken thousands of years. Archaeological evidence shows that seeds were consumed as food even before agriculture was practiced (FLANNERY, 1973). How did hunter-gatherers turn into cultivators? This issue has been studied in interdisciplinary research led by ethnobotany, but the answer is still unknown. One clue that triggered these studies was uncovered in the last century by De Candolle (1886) — the search for geographical locations where plants were originally cultivated. Thanks to this line of work combining genetics and biogeography, Vavilov (1949) found that the farming of certain crops began at and spread from small centers located quite far apart. The assumption then is that agriculture evolved independently at several locations. However, the investigation begun by Vavilov subsequently showed that the original cradles of agriculture were not always small settlements. There is firm evidence that this activity also started in vast areas of the continent. (Harlan, 1971).

In addition to differences as to locations and species, there are two entirely distinct forms of farming practices, especially in terms of seeds (SAUER, 1969; HARRIS, 1972). One plant husbandry technique typical of low humid tropical lands consists of associating several species propagated by vegetative breeding. For this reason it is known as "vegetative farming". This modality includes banana, yam, and sugarcane crops started in Southeast Asia; Dioscorea and kaffir beans in Africa; manioc, other Dioscorea, and pineapple in South America. The other agricultural tradition is typical of dryer subtropical climates. It consists of plantations revolving around seeds because they start by sowing and

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end with the harvesting of grains. This category of farming includes: corn, originally from Central America; wheat in the Middle East; sorghum in Africa; and rice in Southeast Asia.

Vegetative farming harvests roots, tubers, bulbs, stems, leaves and fleshy fruits, usually rich in carbohydrates but poor in lipids and protein. The assumption follows that these foods were eaten with others of animal origin obtained by fishing or hunting. Since these gathering activities are known to predate the taming of animals, their association to vegetative farming indicates that this agricultural technique is much older than seed cropping (SAUER, 1969). Unfortunately, the very nature of vegetative farming products makes it harder to preserve archaeological documents, and Sauer's assumption is still open to discussion. The choice between vegetative and seed cultivation also depends on human cultural factors. For example, in Central America many tubers known as "camotes del cerro" are still eaten and harvested from "milpas" (backyard gardens) or the wilderness. It seems there has never been any attempt to breed these species despite their obvious value. It is also significant that some Brazilian Indian tribes who practice mainly vegetative cultivation used corn to make liquor while manioc is their only source of starch (SAUER, 1969).

Seed agriculture produces far more concentrated crops also richer in proteins. While this type of crop provides greater nutritional value, it tends to deplete soils much faster. In the Old World, the instability of agricultural ecosystems was further worsened by the practice of single-cropping, while in Central America it has been mitigated by associating corn, beans, and squash. Seed agriculture tends to move on to new areas and ultimately encroach on traditional vegetative cultivation. There is plenty of evidence that this occurred independently in America, Asia, and Africa (HARRIS, 1972). At certain locations agriculture is quite eclectic and both farming techniques are used together. Such is the case of Peru during the pre-Columbian era. Vegetative crops such as potatoes, "Oca" *(Oxalis tuberosa),* "ulluco" (*Ullucus tuberosus),* "ysañu" *(Tropaeolum tuberosum),* and sweet potato *(Ipomoea batatas)* were found side by side with seed crops such as corn, beans *(Phaseolus lunatus),* "quinoa" *(Chenopodium quinoa),* "chocho" *(Lupinus mutabilis),* and many others (HEISER, 1973; FLANNERY, 1973).

Seeds gradually became more important to an increasingly greater number of civilizations. In the Middle East this change probably happened between 7500 and 6750 B.C., when grains were first cultivated, and around 5000 B.C. in South America and China (respectively corn and rice) (HEISER, 1973; FLANNERY, 1973). As seed crops gained ground so did the belief that seeds were not something that could be manufactured. People became increasingly aware of the need for a bank of well stored seeds to start each farming cycle. This is powerfully documented in the finding of barley seeds in ancient Egyptian tombs (DE CANDOLLE), and of corn grains and "quinoa," peanut, green pepper, and squash seeds next to ancient Peruvian mummies (TOWLE, 1961).

Many centuries passed since the beginning of agriculture, during which several farming traditions evolved with little or no communication between them. This isolation was not broken until the 15th and 16th centuries, when European started to cross the oceans and crops fast spread throughout the world. The struggle to secure useful plant seeds and seedlings, especially from the tropics, was the root of remarkable developments, from buccaneering to gallant episodes and even shades of contraband and diplomatic pressure.

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For example, coffee was taken by van Horn de Moca from Arabia to Holland in 1616, and coffee plantations were established in the Dutch colony of Ceylon in 1658. In 1706 the Amsterdam Botanical Garden sent a coffee plant to each of the major European botanical gardens. A specimen was sent in 1714 to the "Plant Gardens" in Paris as a gift to Louis XIV, who entrusted the plant to botanist Antoine Laurent de Jussieu. From this plant's seeds came the coffee plantations of the Martinique (HAARER, 1964) and later of the French Guyana. It is known (TAUNAY, 1945) that strict official orders were violated and some coffee seeds were smuggled out of Cayenne and into Brazil in the pockets of Melo Palheta as a courtesy of Mme. d'Orvilliers, the kind wife of the French governor of Guyana.

In contrast with these polite episodes, there is the case of the breadfruit tree *(Artocarpus incises, A. altilis).* It was first noticed in the South Pacific islands during Captain Cook's famous journeys and taken to America with the use of violence and brutality. Aware of the nutritional value of the tree's starchy fruits, in 1789 some English farmers from Caribbean islands arragned for Captain William Bligh, a former officer of Captain Cook, to travel to Polynesia in command of the HMS Bounty to bring some seedlings of this tree. The purpose was to grow the breadfruit as a cheap food crop to feed the slaves who worked in English farms in the Antilles. Around 1,000 small seedlings were taken aboard the HMS Bounty, but the cargo did not reach its destination because of a mutiny on board. Part of the crew settles in Pitcairn Island. After reaching Timor with the 18 men left behind with him on a fragile boat in the Pacific Ocean, Captain Bligh went back to Oceania and delivered the seedlings. Unfortunately, the ploy failed because the African slaves would not accept the new food that was being forced them. The tree was spread through the American tropics as an ornamental plant (HEISER, 1973). It is also used to provide shade for coffee and cacao plantations in Venezuela.

The story of cacao seed propagation by man was also quite eventful. In 1525, Spaniards took the seeds from Central America to Trinidad and Venezuela. Somehow, the Dutch managed to take some seeds to Curacao and later to Ceylon, the current Indonesia, and Sao Tome Island. From the latter, around 1878 or 1879 an anonymous African worker carried seeds to West Africa, now the number one cocoa producing area (BAKER, 1968).

Perhaps the last episode in this cycle of skirmishes and monopolies over seeds was the rubber tree issue. This Amazonian rubber tree, for a while a highly profitable Brazilian monopoly, was the target of two British attempts to smuggle seeds to their Asian colonies. One was undertaken by Farris in 1873. He carried some seeds from the Amazon to Kew Gardens in the U.K., and from there to Calcutta, India. The plantules did not survive the harsh climate during the journey and the attempt failed. The outcome of the second attempt, very carefully planned by Wickham in 1875, was quite different. 70,000 seeds of the best rubber trees of the Tapajós river were gathered (which must have been very time consuming and a lot of work) and shipped in the SS Amazonas. At that time, this ship held the time record in crossing the Atlantic Ocean by a steamer. Only 3,000 seeds out of the total did germinate in the greenhouses of Kew Gardens. The plantules were quickly and carefully transferred to the Peradenya Botanical Garden in Ceylon, where they grew into 1,900 trees. In 1910, Asian rubber plantations grown from Peradenya seedlings produced a mere 11,000 tons annually, while in the Amazon rubber tapping was reaching its boom. Just four years later, however, Asian production exceeded its Amazonian competitors. This was the result of systematic use of scientific methods to solve the problems of rubber plantations. Another advantage was that in Asia there were no outbreaks of fungal plagues such as the disease known as "tip rot," caused by *Dothidella ulei.*

By 1939, 98% of all the world rubber production (1,500,000 tons/year) came from Asia (HILL 1965). Japanese military occupation throughout Malaysia during the Second World War temporarily stopped natural rubber supply to the West. But by then natural rubber had become just a simple supplement to synthetic rubber. Several other alternative plant sources had been discovered also. Examples are *Taraxacum koksaghyz,* (a small herb from Turkestan that for many years supplied the Soviet Union with rubber), and "guaiule" *(Parthenium argentatum)* from the southwestern United States and Mexico, among others.

Shipping seeds and seedlings from one region of the world to another was not always successful, however. A typical example was the attempt made Australian Governor

Arthur Phillips. In 1787 he imported a cactus of the *Opuntia* genus together with its scale insects, in the hope of producing a natural dye. The *Opuntia* became a terrible invading plague that was not brought under control until much later when an insect *(Cactoblastis cactorum)* that is a voracious predator of this plant's seeds was imported from Mexico (BAKER, 1968).

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Accidents of this kind helped bring home the fact that transplantation of seeds should be done first in careful pilot trials before moving into large-scale production. An example of well-organized and responsible action is the Seed and Plant Introduction Section of the United States Department of Agriculture. This agency founded in 1898 has already introduced 350,000 kinds of plants and made over more than 150 prospective exploration trips abroad (BURGUESS, 1971).

## 2. IMPROVEMENT AND CONSERVATION OF SEED BANKS

Since the early days of agriculture a painstaking effort has been made to improve and select plants more suitable to our needs. This mutual adaptation has happened to such an extent that it is hard to think of mankind surviving without the selected seeds of cultivated plants. It is also true, on the other hand, that many of these plants would have vanished in a few short years if humans were to disappear. This has happened often because of man-made artificial selection against the grain of natural selection. Under natural conditions, for example, simultaneous blossoming and synchronized seed maturation is not desirable (a whole generation would be endangered if adverse weather conditions occurred). Grains strongly attached to spikes or pods — e.g. all contemporary cereals, in contrast with their wild newly-domesticated ancestors — would have a hard time propagating without human assistance. Fast and synchronized germinating seeds with no inhibitors or other obstacles to germination offer another type of organization very convenient for us. If left on their own, however, they will certainly fall prey to competing non- cultivated species. They do not spread the development of their scions in a timely fashion and rely on favorable coincidences often not found in nature. And what about plants that have lost their seed producing ability? They would have the fate of all apomictic species: a tremendous success while environmental conditions are favorable, and a complete failure as soon as environmental circumstances turn against them. Their adaptability is nil because they are too much alike, and have no "unfit individuals in reserve" from which "tomorrow's fit" may emerge. The fates of cultivated plants and men, therefore, are linked precisely because of the man-made improvements to these plants.

The ancient history of this improvement is still quite obscure, and again here there is sharp contrast between vegetative cultivation and seed cropping. In vegetative cultivation, selection was necessarily achieved by the predominant breeding of the fittest individuals. This probably shortened the development time of improved clones but also increased the risk that they would be lost more often. For example, it is well known that Venezuela had excellent sweet potato clones which vanished during the Spanish conquest wars simply because they failed to be planted (SAUER, 1969). In seed agriculture, selection effects must be slower both because of genetic recombination in cross breeding, and because many desirable mutants are recessive. It should not be forgotten that prior to the turn of the century all improvement efforts were entirely empirical since sexual reproduction mechanisms in plants and the basic genetic heritage laws were unknown.

Early efforts in contemporary plant breeding seems to be due to Welinder in 1886, in Svalof. His goal was to improve and stabilize the quality of cereal seeds produced in southern Sweden (COWAN, 1972). From these pioneering days to date, enormous progress has been achieved in this field, thanks to the work of several experts throughout the world. Basic genetics is the mainstay of all these practical results.

However, the efficiency of high yield cultivars is a serious threat because improved varieties tend to crowd out less efficient ones from the market and cause them to vanish entirely. Then, if high-yield cultivars are struck by a very aggressive plague of some devastating disease, we may suddenly find that there are no "genetic base stocks" to start over. This was clearly evidenced already when 98% of the corn cultivars introduced in the United States before 1958 and 90% of soybean cultivars simply vanished (JAMES, 1967). Furthermore, even with great luck and skill, producing a new, resistant and high-yield variety takes time. Therefore, the proper scientific infrastructure has to be in place if this all-out war against parasites and plagues is to be won. A vital part of this infrastructure consists of germplasm banks, which might be renamed "DNA pools," to use a state-of-the-art term. Such collections store viable seed samples of a variety of cultivars so that potentially useful genotypes may be available for new hybridization programs.

An example of the potential value of a collection of live seeds is the P.I. 178383 wheat variety stored by J.R. Harlan in Turkey in 1948. This variety at first glance would seem to have no commercial value due to its low resistance to cold weather, relatively large size, a tendency to layering, and poor grinding quality. Its value was purely scientific, as an example of wheat variety unadapted to cold climates but requiring weathering (i.e., seeds must undergo cold treatment for the adult plant to bud). Some years later, however, the plant was found to be resistant to four strains of the fungus *Puccinia striiformis, Tillettia caries,* and to several species of the parasites *Fusarium* and *Tiphula.* It became a major source of genes for hybridization programs, and thanks to this finding it is estimated that roughly US$ 3 million in losses are avoided each year in the state of Montana alone (BURGUESS, 1971).

The two main world centers of live seed banks are the "Nikolai Ivanovitch Vavilov Federal Institute for the Plant Industry" in Leningrad, and the "National Seed Conservation Laboratory" of Fort Collins, Colorado, United States (JAMES, 1972). The latter was founded in 1958 and works in connection with Colorado State University.

The facility consists of: a) a ground floor containing all refrigeration and other machinery; b) a first floor with offices and administrative facilities; c) a second floor where the seed banks (eleven rooms with controlled temperature and moisture) and laboratories are located. Each two or five years the seed collections are tested for viability. If it is found to be low, the seeds are immediately sent for planting by a specialized contractor, under strict specifications for growing conditions. In October 1966, this laboratory had 52,000 seed types in storage, with four to five thousand units per sample (JAMES, 1967). Another major national live seed bank is Hiratsuka Laboratory in Japan (ITO, 1972). There are also several specialized live seed banks, and a good example is the "U.S. living collection of perennial *Triticeae* grasses" (DEWEY, 1977) run by the Crops Research Laboratory of Utah State University, in Logan. This collection began in 1969 and was designed for research and international exchange of living stocks of this type of grass. From 1965 to 1977 the lab developed over 50 new species through chromosomal duplication and backcross hybridization.

## 3. SEED IDENTIFICATION, ANALYSIS AND CERTIFICATION

By the mid-nineteenth century, there was already a very active seed trade in Europe. This activity (later extended to the rest of the world), however, had serious drawbacks such as counterfeiting; intermixture with seedlings of other species, including weeds; contamination by pathogenic microorganisms; and low quality seeds (JUSTICE, 1972). The parties involved reacted against this, many of them being seed producers. Each of the drawbacks listed above gave rise to a new line of research work.

To deter counterfeiting and control involuntary intermixing, *seed classification techniques and agencies* had to be developed. The first laboratory especially devoted to this task was created in 1869 by F. Nobbe in Thorandt, Saxony (Germany). Species identification merely through seed traits is an extremely difficult form of artificial taxonomy. Collections and catalogs are crucial for direct comparison. In 1876, Nobbe published the "Handbuch der Samenkunde" and for 50 years this was the main guide book for seed analysis and identification. Several other books on this topic were subsequently published (MARTIN, 1946, BROUWER & ST?HLIN, 1955; USDA, 1955; VAUGHAN, 1970; DELORIT, 1970; CORNER, 1976). The neotropical region is sorely lacking in this kind of information. Some preliminary studies (cf. SENDULSKY, 1965, 1966) have pointed out how important it is to catalog the shapes of native fruits and seeds. Their structures are closely linked to broader issues of biological interest (HARPER et alii., 1970). Several laboratories all over the world survey and coordinate this kind of data. The two leading examples are the Vavilov Institute in Leningrad, and the "New Crops Research Branch" of the Department of Agriculture, in Beltsville, Maryland, U.S.A. (GUINN, 1972).

In addition to producing and identifying, it is necessary to *evaluate the potential of seed batches* (JUSTICE, 1972). This has been pursued intensely since the turn of the century and resulted in creation of two specialized associations. One of them — the "Association of Official Seed Analysts" —was founded in 1908 and its membership consists mainly of laboratories and individuals in the United States and Canada; it publishes the "Proceedings of the Association of Official Seed Analysts of North America" (New Brunswick). The other institution operates on a broader scale. It is the "International Seed Testing Association," founded in 1924, and publisher of "Seed Science and Technology". Generally speaking, the two key issues addressed by seed analysts are: 1) assuring that the samples analyzed are truly representative of seed groups or batches; and 2) making sure that tests and experiments made with the samples provide conclusive findings that can be duplicated in actual field crop conditions. The problem of obtaining representative samples has led to the development of several ingenious devices to collect large samples and subsequently break them up into smaller lots in laboratories (USDA, 1952; JUSTICE, 1972). Identification issues involved in laboratory analysis often go beyond the species level and must also determine variety types accurately. In addition to classical laboratory trials, this also requires cultivation in nurseries and in small field parcels (COWAN, 1972; JUSTICE, 1972). Seed germination analysis trials involve not just what physiologists call germination (which results in the budding of a part of the embryo), but also seedling development. This is justified from the practical standpoint, since the purpose of analysis is to evaluate the ability of a batch of seeds to effectively grow into normal plants. Seed health tests are particularly delicate: "Fighting parasites transmitted by seeds cannot be an isolated action. It must be permanent and become a surveillance exercise at all stages of seed production and use. This contributes to overall plant protection and therefore is not just part of an integrated effort — it must begin with the use of healthy seeds" (ANSELME, 1975).

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The climax in developing procedures to preserve and assure seed quality is no doubt *certification.* Before granting a certification label, certifying organizations examine, stipulate, and inspect the crop for anything that might affect seed quality: crop location; local wind conditions; adjacent crops; planting and maintenance techniques; harvest procedures; storage and shipping methods; labeling, etc. Right now, several international agreements are being negotiated to ensure standardization of analysis and certification everywhere in the world (ANSELME, 1975). This whole effort has a very obvious practical reason: because of improved shipping efficiency, no region is safe from the consequences of negligence by others, especially in terms of diseases and plagues. On the other hand, it reflects the philosophy that selected seeds and anything related to them constitutes a heritage of mankind.

## 4. THE NEED FOR BASIC AND APPLIED RESEARCH ON SEED GERMINATION

Despite the pessimism of some individuals, relations between human groups — whether in regard to seeds or anything else — tend to move away from the predatory, covert, and monopolistic approaches typical of the 15th and 16th centuries. Now most of the relevant scientific information available is rapidly publicized. Thus, quality of life priorities are set according to each group's ability to amass information and research funds in a timely fashion to facilitate the discovery and application of new data and interactions. It is therefore vital to realize that the mass of information available is so considerable and varied that even a mere survey of the list of data already gathered demands a modicum of organization. On seeds specifically, for example, consider the "Bibliography of Seeds" published in 1967 by Dr. L.V. Barton from the Boyce Thompson Institute for Plant Research in Yonkers, N.Y. (BARTON, 1967). Compilation of this listing of published works was started by the well-known seed physiology expert Dr. William Crocker when he was at the University of Chicago. It proceeded when he moved to the United States Department of Agriculture and subsequently, in 1924, to the Boyce Thompson Institute. At this last institution, Dr. L.V. Barton took up the task of organizing the files, covering an enormous variety of references until 1966. The list contains 20.140 titles but is nevertheless incomplete.

For any country or region to benefit from scientific and technological progress seeds, it must have an infrastructure ranging all the way from libraries and documentary collections to experimental fields, technological and basic research laboratories, and biological reserves. Only well-trained individuals and institutions, with their respective ramifications, can provide the much-needed problem solving capabilities through a free exchange of information and questions. Such structures generate the ability to develop realistic and insightful plans.

Certain very real situations must be considered here to point out why there is an urgent need to raise the awareness of Latin America in general to the need for research on seeds and germination.

Eucalyptus and coniferous plantations have spread in nearly all neotropical regions, in clear contrast to the dearth of similar initiatives using native tree species. If the planted timber market were more diversified, the demand for greater variety and higher volume of this raw material could be more adequately met. What is not always so clearly understood is that native tree planting cannot be effected without accurate data on how their seeds germinate; how plants grow; what requirements, tolerances, and ability these plants have to utilize resources from environment; and what yield is expected of these crops. The shortage of data is such a constraint that eucalyptus and coniferous plantations extend even to areas where slash-and-burn practices are used every year, a tradition difficult to break. The fire hazard in vast areas planted with trees that mainly produce essential flammable oils is lower than the risk of dealing with species not fully studied.

A second reason why seed germination studies in neotropical trees are a pressing need is that they are crucial to protect a number of species from extinction. In fact, extraction (or unmanaged) exploitation tends to deplete the species so harvested. An example is the "freijó" wood *(Cordia goeldiana),* an excellent hardwood from the Amazon for light aircraft wing construction and wooden barrel making. The market for this wood has virtually disappeared due to of lack of regular supply. The same will happen soon to the "boil de rose" *(Aniba rosaedora,* A. *duckei),* another wood from the Amazon that has been intensively exploited for its essential oil (it is an industrial source of linaleel) produced by a steam flow form of wood distillation. Many other species are endangered because no one knows how to grow them so as to offset the destruction caused by its extraction exploitation, use as firewood, or simply burning to clear the land.

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There is a third reason to study without delay the seed germination process of several tropical species already recognized as useful. The information will be essential to any breeding initiative for these species because genetic work customarily involves hybridization, and consequently sexual propagation. In addition to the need to learn about what these seeds require to germinate, there are other issues such as devising new storage methods to keep the seeds viable longer than the ones available today. A botanist with 17 years experience in tropical rainforest studies in Southeast Asia made the following statement on the subject: "The lack of dormancy hinders crop breeding, which is becoming increasingly important for development of forestry from planted trees. The same is true of breeding with respect to several regional fruit trees whose ancestors came from rain forests. In short: it is not an overexaggeration to say that development of methods to induce dormancy in tropical rain forest tree seeds is still a virtually unexplored field of research. Its success is crucial for opening new horizons for forestry and horticulture." (WHITMORE, 1975).

Latin America is a vast source of seed germinating problems and their solution would broaden the prospects for practical applications. This vein is virtually unexplored for a number of reasons: lack of stable pioneering research facilities; shortage of trained scientific and technical staff; and absence of specific bibliography. The first of the above causes is sure certainly the most important one, because experts are trained by preexisting talent and pressures for proper research facilities can only arise when enough individuals share a strong interest in the issue. The basic organization of breakthrough laboratories, including seed breeding research, was recently studied jointly by a plant physiologist and an architect (LABOURIAU FIUZA COSTA, 1976).

Aside from these considerations of a practical nature, seed germination studies are of prime importance from the basic research standpoint. The geographic distribution and ecological preferences of several plant species are determined by the range of environmental conditions tolerated by their seeds during germination. Therefore, study of the germination process can contribute to an understanding of many biologic and geographic peculiarities. This type of application should not focus on the present only. It can be used to interpret paleoecological data such as pollination diagrams, for example. Studies on the environmental requirements for the germination of different seeds raise interesting points on natural selection as well as many new issues about environmental control of plant development through a set of low energy signals coming from outside. The dormancy period of many seeds raise basic issues at the molecular level concerning damage repair mechanisms, especially on biomembrane injuries. Studies of seed metabolic patterns both in the growth stage and low activity periods, particularly during germination, are obviously of biochemical interest. Furthermore, since all seeds are products of development processes, they have their own unique organizational patterns and it is essential to learn how these patterns interact with physiological activity during germination.

The physiology of seed germination has many facets and implications and thus the strong interest in studying it from the biological angle.