

BRAZIL'S PROGRAM FOR DEVELOPMENT OF AGRICULTURAL RESEARCHERS

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Brazil regards the application of science and technology to agriculture as a major means of achieving economic and social progress. In the 10 years since the reorganization of the national agricultural research system, marked by the founding of EMBRAPA, agricultural science has become a powerful, productive force in Brazilian society. Major research projects have been carried out and discoveries of world importance have been made.

EMBRAPA aims to change the focus of the relationship between advanced and developing countries from "technology transfer" to "science transfer". It is attempting, after appropriate selection and training of future scientists, to create challenging and rewarding career opportunities in agricultural and related research in Brazil. Only by retaining a large fraction of its best people can a developing country like Brazil build an agricultural research system that will develop the technologies fundamental to the economic growth and stability of the agricultural sector.

Initial base of human resources. The demand for research in Brazil has grown enormously because of the country's high rates of economic growth, rapid urbanization, and increasingly diversified economy, because of expanding opportunities to sell agricultural products on the international market, and because of a better understanding of the role of science in modern society. These factors have also affected the character of this demand so that now, more than ever, research work requires increasingly sophisticated skills. Brazil therefore needs well-trained researchers capable of grasping innovations from abroad and adapting them to its circumstances. The great advantage in this policy is that a substantial part of the

cost of the original research does not have to be borne by Brazil. On the other hand, in view of Brazil's diverse environmental conditions, which differ from those of the developed countries in many ways, generating appropriate knowledge that transcends mere adaptation is a component of prime importance in agricultural research programs.

A decade ago, the quality and quantity of researchers was inadequate for the demand. Brazil had only 3,361 fulltime and part-time research workers in agriculture. Of these, a third were in the Ministry of Agriculture and the remainder were in universities, state governments, private businesses, and other ministries. While it is difficult to measure their capabilities precisely, one indication is graduate work. In 1972, of the 872 scientists employed by the Ministry of Agriculture, only three held Ph.D's and only 93 had completed graduate courses at the master's degree level.

TABLE 1. EMBRAPA: Staff growth.

Year	Research workers	Support personnel	Administrative personnel	Total
1973	12	7	47	66
1974	872	2125	993	3990
1975	1037	2356	1416	4809
1976	1328	2666	1709	5703
1977	1311	2678	1696	5685
1978	1336	2954	1744	6034
1979	1448	3191	1935	6574
1980	1553	3314	1902	6669
1981	1576	3340	1948	6864
1982	1578	3338	1996	6912

Source: DRH — EMBRAPA.

Creation of EMBRAPA. When EMBRAPA began functioning early in 1973, the human resources devoted to research activities available within the network of the Ministry of Agriculture did not present a bright picture. Consequently, EMBRAPA gave the creation of an aggressive training program highest priority. To ensure the success of the program, a policy of promotion by merit was created to reward talent and work in accordance with the standards of domestic and international markets. An intensive recruitment campaign was undertaken to attract to EMBRAPA young people and experienced technicians of talent, and thus build a research staff capable of confronting the great challenge of Brazil's agricultural

development. At the same time, through agreements with international agencies, EMBRAPA acquired the valuable assistance of technicians from other countries. They added their experience to that of Brazilians in order to solve the problems of Brazilian agriculture and advance knowledge of tropical and subtropical agriculture.

A large proportion of EMBRAPA's research staff was sent to graduate school under the auspices of the organization. The proportion of researchers holding or working on advanced degrees (M.S. or Ph.D.) rose from less than 10 percent at the end of 1973 to 46 percent by early 1976.

TABLE 2. EMBRAPA: Costs per research worker.

Year	Research workers no.	Salaries fringe benefits, and other expenses \$ millions	Cost per research worker * \$
1974	872	6.8	7,779
1975	1037	12.0	11,600
1976	1328	23.6	17,742
1977	1311	26.4	20,100
1978	1336	33.2	24,883
1979	1448	34.0	23,492
1980	1573	45.0	28,653
1981	1576	48.3	30,656
1982	1578	58.3	36,973

* Salary is about 55 percent of the cost.

Source: DRH - EMBRAPA.

Principles and objectives of the graduate program. The following are the guiding principles used to develop and implement the graduate training program of EMBRAPA.

1. Researchers should be trained in a way that helps the EMBRAPA system attain its objectives. In particular this has meant taking steps to rapidly alleviate the shortage of researchers, not only for EMBRAPA, but also for other agricultural institutions.

2. The training program should be adjusted to the professional life cycle of the researcher. For some researchers, this cycle begins at the university, when they first accept research fellowships. For the majority, however, the initial step occurs

when they first join a research institution. The cycle can follow various routes for the person who is beginning a career as a researcher, but there are three primary sequences differing in how periods of training and of research work are combined. The starting point is the university.

- a. After completing bachelor's level training, the future scientist joins the research institution and works for up to 3 years. He then takes about 1½ years for master's level training and returns to work for at least 3 years. At this point he returns to school to pursue a doctoral degree, which is completed in about 3½ years. He then rejoins the research institution. In this sequence, the minimum time between entering the research institution and achieving a doctoral degree is 10 years.

TABLE 3. Investment in human resources in relation to the total EMBRAPA budget.

Year	Total budget \$ millions	Investment in human resources *	
		Value \$ millions	Proportion of total budget %
1974	26.3	7.1	27
1975	56.0	13.6	24
1976	80.8	24.5	30
1977	98.1	26.8	27
1978	125.6	24.7	20
1979	154.1	23.4	15
1980	157.5	25.8	16
1981	183.0	32.3	18
1982	220.0	36.4	17
Total	1,101.4	214.6	20

* Includes salary indirect cost, substitution at a cost equal to salary and indirect cost plus direct education expenses like scholarship, fees, and transportation.

Source: DRH – EMBRAPA.

- b. Immediately on joining the research institution, the scientist is sent for master's degree studies, which take about 1½ years to complete. The scientist does at least 3 years of full-time work and then begins studies leading to a doctoral degree – another 3½ years – after which he returns to work. The time from entry into the organization until completion of the doctoral degree is at least 8 years.

- c. Immediately on joining the research institution, the scientist is sent to work on a master's degree followed by a doctoral degree. He then begins full-time work. The time from entry until completion of the doctoral degree is 5 years.

Sequences b and c should both be limited to highly promising candidates who have already shown a strong inclination for research.

Apart from these three sequences, there are innumerable possibilities tending to prolong the time needed for the researcher to attain the top rung from the training point of view.

4. Not every researcher will reach the doctoral level or its equivalent. Some individuals lack the ability, interest, or the will to achieve this goal. Nevertheless, these researchers use useful for the many less complex tasks and they can thus save the time of better trained researchers.

5. It is necessary to train research administrators and leaders. Without leaders and administrators, the implementation of research tasks becomes extremely difficult or even impossible.

6. The university is the fundamental base of all training, and needs to be stimulated and supported.

7. Since society is investing in the researcher and since the researcher himself reaps some of the benefits from this investment, it is proper to demand adequate performance in graduate and other studies, as well as in the professional career that follows.

8. Along with the acquisition of specialized knowledge, it is important that the researcher gain a comprehensive vision of the Brazilian development model so that he will be able to choose his research projects within the context of this model.

Beyond this orientation, it is important to foster in the researcher a sense of the mission of the research organization and the system, so that he will understand its intentions and objectives, its philosophy and manner of confronting problems, and, in this way, feeling like an integral part of the system, he will collaborate enthusiastically and decisively in the tasks shared by all.

9. Since long training periods cause disruptions in relation to the work environment, an effort should be made to ease the difficulties in adapting that the scientist may have on return from training.

10. Creativity should be encouraged as a fundamental principle of training. The researcher's most noble and most difficult task is to formulate relevant questions. Training that emphasizes methodology and theory is of value in this respect to the degree to which it is heterodox and challenging, and is injurious when it is dogmatic, ritualistic, traditional, repetitive, and based excessively on textbooks and formal classes.

11. Because graduate courses impose sacrifices on the researcher and the researcher's family, they require financial compensation during and after the training period.

12. Given the high cost of graduate courses, EMBRAPA and the universities must cooperate closely so that graduate programs and subjects of theses fit the interest of one institution as much as of the other. This joint effort will result in better trained researchers who are therefore more capable of solving agricultural problems.

13. Given the complexity of the research task and the high cost of training, the selection system must be rigorous to facilitate the discovery of individuals with vocations and talents for research, while eliminating those not suited to this type of work.

TABLE 4. EMBRAPA: Cost of graduate and continuing training.

Year	Graduate training		Continuing training	
	N. ^o	\$/person	N. ^o	\$/person
1974	381	17,232	491	869
1975	474	26,562	563	1,109
1976	575	39,495	753	1,348
1977	457	49,407	854	3,657
1978	295	57,270	1,041	4,654
1979	324	55,494	1,124	3,166
1980	316	67,436	1,257	1,984
1981	320	70,065	1,256	5,854
1982	350	83,401	1,228	3,316

Source: DRH — EMBRAPA.

Results of graduate training programs. Under normal conditions, graduate programs should follow a sequence that begins with the entry of the recent college

graduate into EMBRAPA, to work for 2 or 3 years with the aim of demonstrating potential, capacity for adapting to the work, and a vocation for certain scientific areas. After this period, researchers with potential are sent for a master's studies, being able, sometimes (depending on institutional needs and individual capability), to continue directly for a doctorate or, instead, to return to work, acquire more experience, and be considered for doctoral studies.

Since EMBRAPA did not face normal conditions in its first years this sequence was rarely followed. Brazil did not have enough technicians with advanced degrees to meet the needs of EMBRAPA and of other agricultural research institutions.

Therefore the strategy selected was to closely evaluate the existing research staff; those judged capable were designated for graduate programs in Brazil and abroad. An aggressive recruitment campaign was launched in the universities and elsewhere to attract capable young people to EMBRAPA. Most were sent directly into graduate programs or else underwent an "adaptation period" of one year in the research units and then entered graduate programs. The program that was implemented assured, for the next 3 years, an average annual return of 250 researchers with master's degrees.

The early program was weak at the doctoral level mainly because few candidates were ready for more advanced studies. Later, training at the doctoral level was emphasized.

Doctoral-level graduate training. Education at the doctoral level is expensive and requires time: approximately 3½ years beyond the master's program in good universities in Brazil and abroad. Researchers who have had advanced training have a critical role in the work of EMBRAPA. They are better qualified to recognize technologies that are relevant to Brazilian problems and to adapt them to local environment. They have at their disposal the best methodological tools — knowledge of experimental theories and techniques that gives them greater capacity for identifying problems and finding solutions. And, in scientific interchange, wherein professional respect is the main component, it is scientists who have advanced degrees who are in a position to seek help wherever in the world it can be found and, conversely, to offer help when necessary. The essence of scientific interchange is the give and take. When one of these is absent, scientific interchange will not occur with the intensity desirable for Brazil. Furthermore as a result of the knowledge they have, these scientists are bound to play an important role in the leadership, training, and follow-up of the work of young researchers who constitute the large majority of EMBRAPA's scientific staff at present.

While the presence of highly trained researchers is essential to EMBRAPA, there were many difficulties in locating the human and financial resources needed to make this training possible.

The selection of disciplines in which researchers will do doctoral work is critical for building a staff that has a broad outlook that is responsive to the principal interests of EMBRAPA. It is convenient to classify the needed Ph.D.'s into three groups:

- Ph.D.'s who will work only in the central office. Planning, business administration, mathematical programming, etc. are among the fields of specializations of this group.
- Ph.D.'s who will work in the central office and in the national centers. A broad range of specialized disciplines is included here, generally related to subjects that form various components of the agricultural sciences. Examples of specialized training of this group are poultry diseases, genetic engineering, economic entomology, etc.
- Ph.D.'s who will be placed mainly in the central office, national centers, and other research units. These research workers will be trained in a general approach to a specialized field. In reality, the researcher in this category would be called "production researcher". Examples of training areas of this group are animal husbandry, poultry science, pasture improvement, grain production, etc.

Continuing master's level training. The emphasis on sending EMBRAPA researchers for master's degrees has abated, but on a reduced scale the program continues in order to have replacements for the vacancies that occur through retirement, death, or departure from EMBRAPA. Maintaining a level of 100 technicians studying for master's degrees, corresponds to a departure rate of 50 per year, which fulfills EMBRAPA's needs. This number guarantees a replacement rate on the order of 3.2 percent a year, which is satisfactory at this stage when the majority of EMBRAPA researchers are young.

Depreciation of human capital. Graduate training is EMBRAPA's major investment in human capital. Unfortunately human capital can depreciate, and the Brazilian environment has elements conducive to high rates of depreciation: the tendency for salaries to level off, the lack of competitiveness (because there are few researchers with advanced training and few posts aside from the public sector), bureaucratic shackles, the lack of competent assistants capable of turning out the

work, and, finally, the lack of tradition in the areas of research administration and leadership. These are some of the many factors that may jeopardize the heavy investments EMBRAPA makes, which are aimed at acquiring researchers with high productivity.

The depreciation of human capital has two dimensions: one absolute and the other relative. The absolute dimension relates to the loss of knowledge as a result of forgetting. The other dimension, without doubt the more important, is of a relative nature. It is the stagnation or slow progress made in relation to the scientific world, which develops at an accelerating rate. That is, instead of reducing the knowledge differential that exists between what he knows and the boundary of scientific knowledge, the researcher allows the differential to grow. Too many individuals gain substantial knowledge only during graduate school; they learn little in the remainder of their lives, which means that a high relative rate of depreciation of human capital occurs.

The urge to learn new things is spurred by the imbalance that the human being feels between what he knows and what he should know. Factors that make evident the perception of the imbalance and that tend to keep the "state of imbalance" permanent must be introduced into the research organization to motivate researchers to continually broaden their knowledge. The salary scale created, the graduate courses, the evaluation system based on the idea of recognizing merit and talent are measures that tend, to a certain extent, to perpetuate the "state of imbalance". The limited competitiveness that exists, principally among the more advanced level of researchers, the tendency to be intolerant with individuals who question procedures and technique, the lack of graduate students who would stimulate their advisor in the search for knowledge, the difficulties of traveling to meet researchers from other institutions and countries, and the limited international readership of EMBRAPA's publications (because of language) — all contribute to destroying the differential which must exist between what the researcher knows and what he himself feels he ought to know.

There are several measures that can stimulate high rates of learning after graduate training:

Fostering competitive spirit

Competition can occur between research centers, between EMBRAPA state and federal research units and state enterprises, the universities, and the private sector. This competition should be established on healthy terms, not as an unwholesome rivalry. Here the role of the administrator is fundamental, stimulating

the interinstitutional environment when it is apathetic and lacking motivation, cooling things down when the temperature reaches dangerous levels, which jeopardize interinstitutional relations.

Competition can also occur among technicians. The system of evaluation, which restricts promotion to a small group of researchers only, will spur competition. Yet, it is clear that there is a risk of discouraging those who are not promoted. It is therefore necessary to take care to avoid injustice and to provide opportunities for redress to those who think they have been unfairly treated. Self-evaluation needs to be encouraged. This technique has the advantage of focusing the technician's dissatisfaction on himself rather than on his fellow workers' advancement.

Gaining public recognition

The role that everyone plays in the building of a model institution, which contributes significantly to the improvement of national agriculture, should be spotlighted. It is important that farmers, high officials, and the general public recognize the role scientists play in augmenting productivity. Even young scientists beginning their careers should be given opportunities for contact with political leaders, governors, ministers, renowned scientists, and, when possible, with the president of the country. Efforts should be made to create a favorable image in the press and the media, including even seeking to publicize researchers who are at the forefront of the action, citing their names and the work they are doing.

Maintaining a salary scale that rewards work and talent

Ways should be found to keep the salaries of talented scientists from leveling off. Individuals who question scientific norms and procedures may be very creative and their existence in the research organization should, therefore, be protected. A portion of the research budget, though no more than 10 percent, should be devoted to fostering innovative projects, which may not withstand strict scrutiny if judged by the prevalent criteria.

Maintaining a dynamic evaluation system

All technicians should participate in the development of the evaluation system and in its implementation, as well. Patronage practices should be suppressed. Leaders of the national research system need to be alert for administrators who feel their positions are threatened by talented technicians and who seek to maintain control by discouraging creativity.

Creating opportunities for professional recognition

Scientists should be encouraged to publish their work in national and foreign scientific journals and to make contacts with the local press. They should participate in congresses and make contacts with renowned scientists. Meetings between researchers concerned with practical applications and those dealing with standard and related areas should be organized. There should be meetings between plant breeders and geneticists, between social scientists and biologists. In other words, intensive communication should be maintained not only within research units but also among all units. Such meetings might be held on an annual basis and scientists outside the national research system should be invited to participate.

Periodically evaluating the work of the research units

Committees including scientists from the private sector, from universities, and from abroad should be established to evaluate research units (not to be confused with evaluation of individual researchers).

Promoting the training of research administrators

Executive training should be of a theoretical and practical nature. Continual exchange of experience should be fostered between administrators of the various research units and also among these administrators and those of other institutions, public or private, within Brazil and abroad.

Stimulating participation in extension activities and frequent contact with farmers

The greater the participation of farmers in research institutions, the greater the likelihood that researchers will be motivated to work and that they will not become alienated from the reality that they must transform.

Creating a formal system of courses and seminars in the research units

The objective is to simulate a micro-university, thereby guaranteeing the students' attendance. Courses, conducted once a week, might be organized so as to prepare college-educated technicians for master's degree studies and master's level technicians for doctoral studies. A system offering certificates should be established.

Equipping libraries

Bibliographic exchange should be facilitated. Reference facilities should have

work rooms of an adequate size. Bureaucratic procedures should be minimized.

Participation in all phases of research activities

On-the-job training of technical support personnel can be promoted through full participation of research scientists in all research-related activities. Scientists should participate in all field and laboratory work, for contact between them and field technicians, experimental materials, machines, and equipment is important. Otherwise, an "office aristocracy" will be created — individuals who feel field work is demeaning, regarding it as incompatible with their doctoral title. Nothing more harmful can take place. This attitude inhibits the development of the capacity for observation, a fundamental component of all research work.

Familiarity with social and economic realities

Stimulating a more comprehensive understanding of rural problems is a major task for research administrators. Familiarity with the social and economic realities plays an important part in the development of the scientist and stimulates him to work on relevant problems.

Special courses

Opportunities for periodic training in organizations such as international research centers, universities, and private businesses should be given.

Investment in human resources

From 1974 to 1982, EMBRAPA's total research employment was 10,859 man-years, and, of this total, one third was spent in full-time graduate training or short-term courses, seminars, educational trips, and similar activities that are considered continuing training. During their studies, the research personnel had full salary, and that, added to fringe benefits, education allowance, and other expenses amounted to US\$215 million or 20 percent of the total EMBRAPA budget during the 1974-1982 period. This estimate was calculated by considering the theoretical cost of filling the post of each research worker in training with a substitute of similar level. In other words, the direct and indirect costs of each research worker in training was multiplied by two. This assumption might be questioned, yet it reflects the opportunity cost of having a research worker with an M.S. and some years of experience outside the research institution for 4 to 5 years without directly contributing to research. On the other hand, one can argue that if the thesis is related to on-going research at the researcher's institution, it

could contribute as much as his work there. (It should be mentioned that in addition to the EMBRAPA staff in both graduate and continuing training, the program also included 738 individuals from other research institution in graduate training and 2102 participants in continuing training).

As the number of research workers in EMBRAPA has grown — from about 900 in 1974 to nearly 1600 in 1982, the cost per research worker has risen from \$7,800 to \$37,000. Even though salary for the same scale of classification did not increase during the period in real terms, the rising average cost indicates the shift to higher pay scales based on graduate education and merit of individual research workers. The average annual per-person cost of graduate training has increased from \$17,000 in 1974 to \$83,000 in 1982, as a result of shifting emphasis from M.S. to Ph.D. level training and the increasing educational level and corresponding salary of research staff. These figures give some idea of the cost of investment in human resources that is involved in a program of an institution that undertakes, as EMBRAPA did, to change the composition of its research staff from more than 90 percent bachelor's level researchers to 60 percent master's level and only 25 percent bachelor's level in a relatively short time.

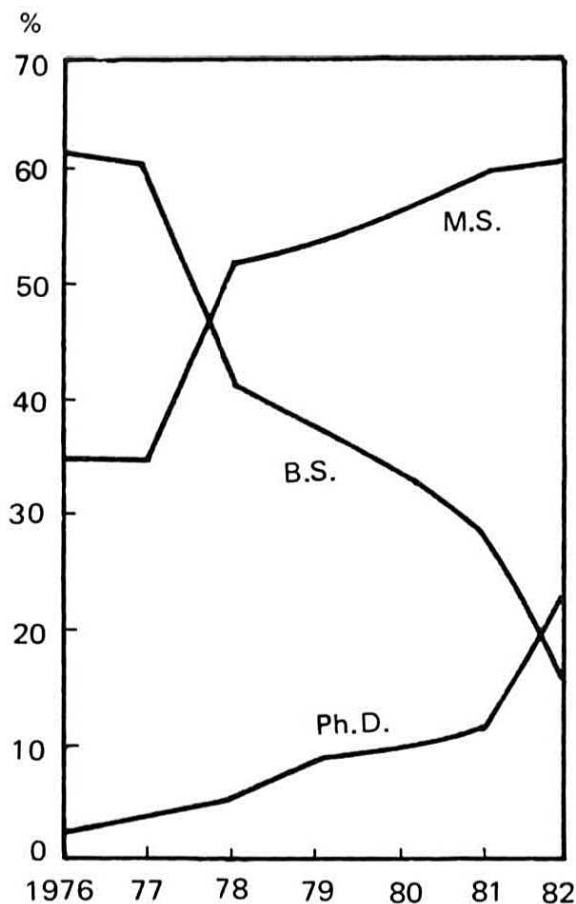


FIG. 1. The changing qualifications of EMBRAPA researchers.

“Knowledge is our most powerful engine of production”. Alfred Marshall.