SCIENTIFIC CORRESPONDENCE

The levels of magnesium and lanthanides in coconut root (wilt)

The measurement of magnesium in wet weight in our paper[1] on a common basis for a human cardiomyopathy and coconut root (wilt) had been questioned[2]. We have repeated the measurements on dry weight basis[3] in the same number of samples from the same locations. The results are given in Figure 1.

The data confirm our earlier findings on the reciprocal relationship between magnesium and lanthanide levels and clearly distinguish three subsets of palms; healthy controls in Manavalakurichi, healthy looking (asymptomatic) and diseased palms in Quilon and Alleppey districts. The marked difference in the levels of magnesium and lanthanides in the healthy controls and diseased palms is obvious.

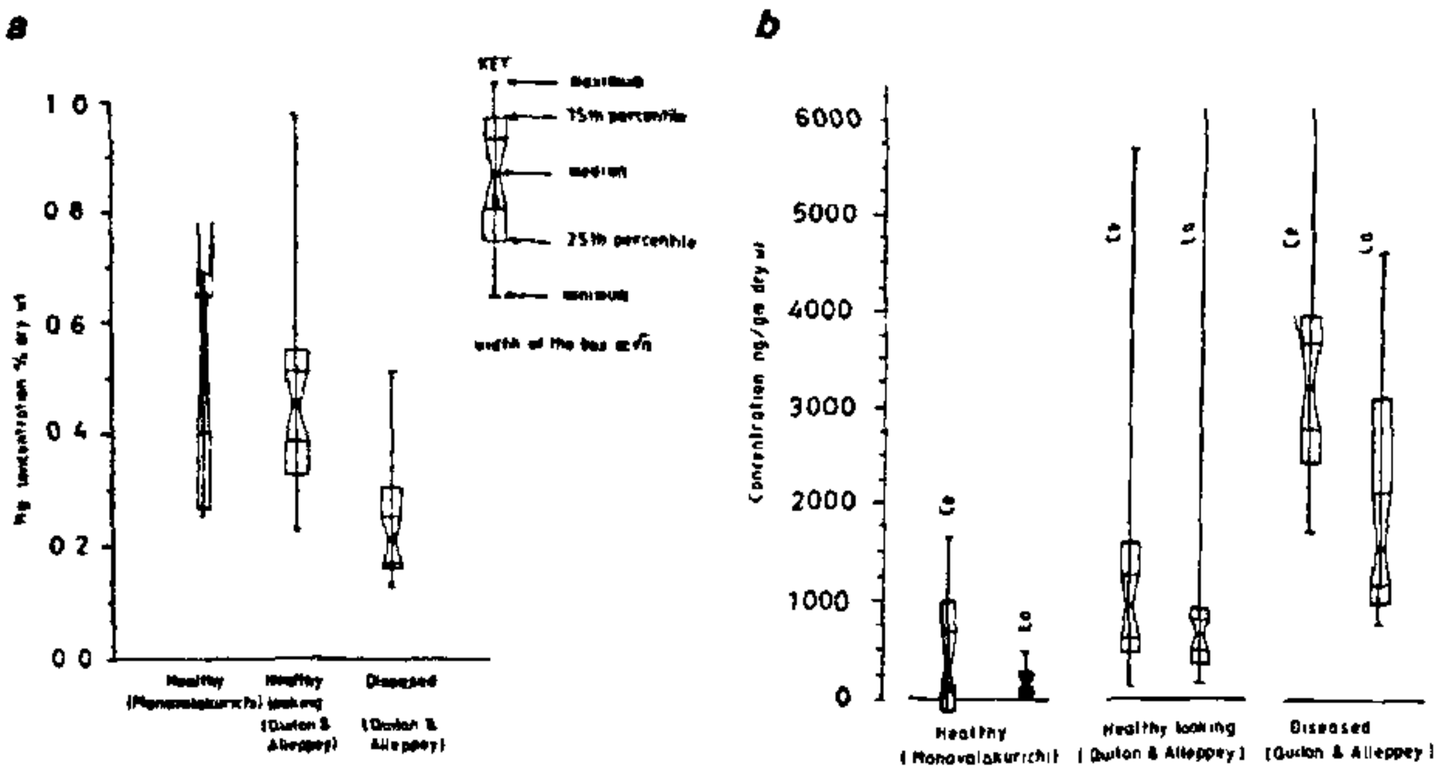

Figure 1 *a*, *b*. Box plot of magnesium (*a*) and lanthanide levels (*b*) in three subsets of coconut palms. Pr and Nd were not significantly different when compared with controls. Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb and Lu were below detection limit.

1. Valiathan, M. S., Eapen, J. T. and Mathews, C. K., *Curr. Sci.*, 1992, **63**, 565–567.
2. Nair, M. K., *Curr. Sci.*, 1993, **64**, 279–280.
3. Jones, J. B., in *Official Methods of Analysis of the Association of Official Analytical Chemists* (ed. Williams, S.), AOAC, Arlington, VA 22209, USA, 1984, pp. 38–64.

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COMMENTARY

Towards a new technological frontier

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I am grateful to my good friend Thyagarajan for inviting me to deliver this year's Nayudamma Science Foundation Lecture. I have had the good fortune to know Nayudamma personally. What struck me most about him was the personal leadership and inspiration he provided and the technological slant he gave to our scientific efforts. India has always had a long and distinguished line of science administrators but it would not be wrong to say that Nayudamma was one of the very few who understood what technology was all about. He understood technology not just in terms of technology but also in terms of the social context in which it operates. Nayudamma's work in leather should not be seen merely as a grand technological effort but more fundamentally as an effort at basic social engineering. It was this symbiotic marriage of technological possibilities and social needs that characterizes Nayudamma's work from that of most other people who have managed our affairs in science and technology. My acceptance of Thyagarajan's request today is my humble tribute to the memory of an old departed comrade-in-arms Nayudamma who had a mind that relentlessly challenged conventional wisdom and it is in this spirit that I have chosen this evening to take on some of the 'sacred cows' that have governed the formulation and implementation of our technology policy so far.

Before I do that, however, let me place technology in its overall economic context. Over the last two years we have begun a bold experiment in economic restructuring. However, it would be wrong to see this as a sudden and unexpected happening. The conventional assumptions of economic policy have been under review throughout the 1980s and what we are now seeing is the cumulative effect of over ten years of sustained questioning of all the sacrosanct beliefs, ideologies and traditional

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assumptions that have guided and governed the conduct of economic policy in this country. In fact the process of intellectual search for alternatives in economic policy began in the late 1970s. There was the Dagli Committee on Controls and Subsidies in 1978. Then, we had the Alexander Committee on Trade in 1979. Subsequently, we had a whole set of reports prepared under the guidance of the late L. K. Jha which came to be known as reports of the Economic Administration Reforms Commission. The Narasimham Committee on Shift from Physical to Fiscal Controls in 1984 was another milestone. The Arjun Sengupta Committee of 1984 provided the backdrop to our new approaches to management in the public sector. There was also the Committee on Trade Policy which I had the privilege to head and the report of which was submitted in 1984. All these provided the intellectual fodder for the liberalization and economic reforms during the 1985–90 period which, in turn, served as the springboard for the radical economic restructuring that was initiated in 1991.

I say all this not just for historical interest but to draw attention to the fact that we have over a decade's experience in the questioning of every facet of our economic ideology. At the end of ten years we now have a set of basic principles which govern our economic policy. These basic principles can be summarized as:

Competition. Without competition there can be no efficiency. The only way, history teaches us, economic agents will become efficient is when there is a threat to entry and the fear of exit. There is no alternative to this. The new economic policy is founded on this principle: that it is competition, more competition and yet more competition that will bring productivity in all economic activities. The only issue of relevance is not indigenous or imported, large or small, public or private but really whether competition exists or not.

Restructuring of the public sector. Over the years, the public sector in India has grown in a haphazard and in an *ad hoc* manner. It is now clear that we need to reorient the activities of the public sector so as to focus them into essential areas. Where there is no alternative to public investment, where they operate, they have to run profitably and commercially. Social objectives are fulfilled not by running up losses but by creating adequate surpluses. Most of the conventional arguments for the public sector have disappeared and the private sector can now take on an expanded role, thus allowing public investment to be concentrated into areas where there is really no alternative to public investment, take education, health, family planning, agriculture and rural development.

Greater role for direct foreign investment. It is clear that equity is the cheapest way of attracting foreign resources. Yet throughout the 1980s, we ignored this simple principle and resorted to high-cost commercial borrowings. Equity is the only non-debt creating form of resource-inflow. Capital is available and if we have the right policy environment, we should be able to attract foreign investment both for the sake of attracting capital and also as a source of technology, management and marketing expertise, and as a channel for increasing exports.

Greater role for foreign trade. In the 1950s, Indian economic policy operated on the assumption that exports are neither necessary nor will they be feasible. By the 1980s, this pessimism had been replaced by guarded optimism. It was now felt that exports were necessary but were not feasible. But all through, our approach to foreign trade was that the world must open its market for Indian exports whereas we should keep our markets closed. Our notion of foreign trade was increased exports and no imports. This has changed and we are now recognizing that for us to export we must also be in a position to import and allow access to our own markets.

The assumptions in this new approach are that we must move from a bureaucratically guided and regulated regime to a system where decisions on production, technology, scale, location and other such matters are taken by entrepreneurs themselves. Competition in the new environment does not mean the ability to manoeuvre around the babus and the bhawans but it means increased market share. Competition means that the market picks the winners and separates the men from the boys and rejects the losers. It does not mean that a group of the so-called wise men decide what is good for the rest of the economy and society. In the new environment the role of planning and the role of the State is to undergo a radical transformation. It has to be promotional, not regulatory. It has to be facilitative, not obstructionist. It has to be cooperative, not adversarial. It has to be responsive, not coercive.

And the new approach in no way militates against our traditional objective of self-reliance. The true index of self-reliance is the ability to pay for our imports through our exports. In the past, self-reliance has been only a slogan. Now it has to be an empirical reality. It can happen only when our old ideas of Aid, not Trade, of Borrowing, not Investment changes and are replaced by new ones of Trade, not Aid, of Investment, not Borrowing.

I thought that I should begin with this overall economic perspective because this provides the background of what I wish to say. My point is simple. We have challenged all the conventional assumptions of economic policy over the last decade. It is time for us to initiate a similar questioning of the conventional assumptions that have governed science and technology policy in this country. The tenets of the new economic policy, namely competition, increased foreign trade, increased role of foreign investment and a different role for the public sector have their own implications for technological development which we need to articulate. But more fundamentally we need to look at science and technology policy from its very roots and ask ourselves whether we do not need a whole new paradigm itself.

The first aspect of science and technology policy that I would like to question is the stranglehold of the scientific community. To think that technology is just applied science or that technology comes out of the work of research laboratories is, in my view, a very limited view of technology. We have had a few scientists determining what the substance and style of our technology policy should be. These are important but they are only a part of the whole picture. Technology is a commodity, technology is design, technology is engineering, technology is marketing, technology is not just a result of a 'science

push'. This is the first area that we should be clear on. Technology is as much 'demand pulled' as 'supply pushed'. Much of our technological effort can be characterized as solutions looking for problems. We need a better convergence between technological possibilities and societal needs. Nayudamma had understood this nature of technology. He understood that the user and customer have as much a role in determining the nature of the technological effort as the scientist and technologist. He understood that technology was a tradeable commodity. He understood that technology can be acquired, purchased and mobilized. He understood all links in the innovation chain starting from research to commercialization. We need more Nayudammas influencing our technology policy today.

Second, I think that we have laid far too much emphasis on technology development. It is not the development of technology *per se* but it is the commercialization and application of technology that leads to growth and competitiveness. It is said that most things have been invented in the UK, innovated in the US and commercialized in Japan. Latecomers like India should not repeat the historical growth cycle of the advanced countries. We have one great advantage—we can leap-frog but so far we have been like frogs in the well. Our technology policy priority must be to acquire and mobilize technology from whatever source and apply it speedily to increase productivity, efficiency and competitiveness. That should be our overriding preoccupation—not development alone but commercialization, application and diffusion of technology throughout the production structure. It is enough for us to have a few showcases of technology. Technology has to permeate all through the economic system.

The third assumption of technology policy that I would like to challenge today is the whole notion that innovation is 'white collar' and 'big bang' in nature. We have enough examples to show that while white collar R&D is important in some areas, it is really 'blue collar' incremental change brought about at the shop-floor level that results ultimately in competitiveness. Innovation therefore is not a one shot process. It is a continuous and on-going process. It is an activity that is carried out not just in R&D establishments or by R&D personnel but by the shop-floor workers, by the foremen, by engineers, by workers at the cutting edge. The nature of innovation therefore is different than what we think it is. Just increasing investments in R&D will not suffice. What is important is the nature of the R&D effort, how the R&D effort is structured and what its content is, how it is defined and how it is organized and managed.

Fourthly, I would like to draw your attention to a very interesting feature of modern technological innovation. Technology is making all conventional assumptions of size and scale irrelevant. Technology is calling into question all our assumptions as to why we should have natural monopolies. For example, all through the 1970s we believed that the bigger the fertilizer plants, the more energy-efficient they will be. We standardized our ammonia plants at 1350 tonnes per day. Today you have technology which is equally cost-effective at 400 tonnes per day. The implication of this is that the fertilizer industry need not be only in the public sector and it need not be only a big industry. To take another example, in a service industry like telecommunications, the arguments for telecommunications to be in the public sector is that it is a natural monopoly. However, there is technology today which has completely challenged this argument. In a country like Britain you have two competing suppliers of telecommunication services providing a choice to the customers. The same is true in the US and other developed countries. Economies of scale are being replaced by economies of scope and design. Thus, modern technology provides us with the tools for making small-scale decentralized production, cost-effective and efficient. But not small-scale the way we define it, which is a fiscal artifact, not an economic reality.

The fifth assumption that I would like to challenge is borne out of another trend in modern technological growth which is very striking We have tended to operate on the one technology–one industry principle—on the assumption that if we want technology in electronics we should set up R&D institutions in electronics; if we want technology development in petrochemicals we should set up R&D institutions in petrochemicals and if we want technology in capital goods, we should set up R&D in the capital goods industry. However, in recent times, we see evidence that impetus to technological innovation and growth coming not just from within the discipline and industry itself but also from outside that discipline and industry. Thus, the capital goods industry has been revolutionalized by developments in electronics. The electronics industry has been revolutionalized by developments in material sciences. Medical science has been revolutionalized by microbiology. The point is that conventional barriers have broken down and they are no longer sufficient. Technology, thus, has to be a process of intense intellectual fermentation and cross-fertilization involving a variety of disciplines. In fact, in the 1980s it used to be said that technological effort is inter-disciplinary in character. Today, that technology effort is not just inter-disciplinary, it is trans-disciplinary. It has gone beyond the confines of one narrow discipline or industry. This calls for a change in our mindset, in our education institutions, in our research laboratories and among all our professionals. I have served as India's Ambassador in the US for two years and I have visited many leading American institutions. I have been to many Indian academic institutions too. Now, when I go to the IITs, the first thing that strikes me are those concrete boxes that we call departments—one box is called the chemical engineering department, a separate box is called the electrical engineering department and so on. When I went to American universities I did not find these concrete boxes. I did not find separate buildings for departments but what I found was intermingling of various disciplines.

Sixth, we have tended to see science and technology largely as a problem of hardware, as an effort to developing new products and new processes. But there is another aspect of technology and that is its organizational dimension. Many of the great innovations that have increased competitiveness have been organizational innovations and not so much scientific or technological breakthroughs. The assembly line was a fundamental organizational revolution which led to technological growth in the American automobile industry. The main factor behind Toyota's international success is not so much improved technology but a revolutionary method

of inventory control called *Kan-ban* or the 'just in time' method of inventory control. It is the organization of men and material that influences productivity, not just hardware. Thus, organizational change is as much a part of technological advance as science and conventional engineering. In our country we have very few examples but I can think of Kurien and NDDB as an outstanding example of organizational redesign which has enormous implications for the delivery of science and technology. There are many areas in which this managerial restructuring is called for as a necessary component as technology policy.

All this, of course, does not mean that there is no role for publicly funded research and development and technological activities. There are areas like pre-competitive R&D, generic technologies, standards and support infrastructure where public investment will still be required. In social sectors, too, publicly funded R&D will predominate. But here too I must challenge conventional wisdom. How long can we afford a situation in which 45% of our science and technology investment go into atomic energy, space and defence. Scientists ask for more resources and they have a point that we are not providing enough but the real question is what are we doing with what has been provided. Does the pattern of resource allocation within scientific sectors reflect social needs and priorities? What is the productivity of our investments? Are we using what we have been given in the optimal manner?

Seventh, we need to rid ourselves of the caste system that we have introduced into technology. For too long, we have maintained the wholly erroneous distinction between hi-tech and low-tech. Somehow, we are fascinated by superconductivity, by supercomputers and by advanced space technology. But the same fascination is not exhibited for improving the quality of the tools which millions of our artisans use, of improving the loom of the millions of handloom weavers, of improving designs and processes of a whole variety of activities which provide employment to the majority of our countrymen. It is time for us to do away with invidious distinctions. Technology is simply an improved way of doing things. Technological inputs are necessary in all areas in our services and manufacturing activities. Just as we have hi-tech and low-tech, we have had sunset and sunrise industries. To call biotechnology a sunrise industry and the jute industry a sunset industry is completely wrong. The jute industry is critical to our country but it is an example of industry that has been starved of science and technology inputs. What we need is not hi-tech or low-tech, sunset or sunrise but practical technology, technology that addresses problems in the field and technology that adds value and improves productivity.

Ultimately, technology is about people. There is no shortage of technologists in this country, but we have failed to inspire them. We have failed to create organizations that enthuse and motivate, that nurture creativity and talent. Very few organizations in this country can be called truly innovative and as providing an environment in which entrepreneurship flourishes. It is this human element of technology that we must take note of. Managing technology is itself a technological effort but you do not have to be a scientist or technologist to be adept at it. When I was in the US I used to ask many young men and women why they do not return to India. The answer invariably would be that our scientific departments and institutions operate as closed shops and operate along conventional bureaucratic lines where hierarchy counts; where the colour or absence of hair is more important than what is inside the brain and where pedigree is more important than a degree. We must totally refashion our scientific and technological institutions to take into account the emerging challenges. Otherwise we will be condemned to irrelevance and second-class status.

I am sure that I have not provided any definitive answers today but we can provide answers only if we ask the right questions. I thought I will utilize this opportunity today for a diagnosis. It is not my intention to criticise and belittle what we have accomplished but we can ill-afford to rest on our laurels. The time has come for introspection and to ask ourselves how it is that in spite of the highest political support, much of our scientific and technological effort finds no practical application. It is time for industries, research institutes and government to get together to work out how we can refashion our technological efforts in order to derive maximum advantage for the good of society at large.

Ladies and gentlemen, I hope I have not been alarmist and painted a bleak picture. But we owe it to the memory of Nayudamma and to future generations that we shed much of the dead weight and shibboleth that have dragged us steadily down. We have to recover our elan and self-esteem by our resolve to free India from fear and want through the pursuit of technology in critical areas—areas of importance to our people. Thyagarajan and his band of dedicated workers are striving hard towards this goal. Let us pledge our support to them. Only so shall we recover our rightful place in the competitive world.

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