CHAPTER 4

THE GENERATION OF INTERNATIONAL AGRICULTURAL SCIENCE KNOWLEDGE

> "Few scientists think of agriculture as the chief, or the model science. Many, indeed, do not think of it as a science at all. Yet it was the first science - the mother of all sciences; it remains the science which makes human life possible; and it may well be that before the century is over, the success or failure of science as a whole will be judged by the success or failure of agriculture."
>
> (A. and J. Mayer, 1974)

Agricultural Development

In their book, To Feed This World: The Challenge and the Strategy, Wortman and Cummings outlined what they termed were the three eras of agricultural development throughout world history.

The periods comprised:

1. The emergence over thousands of years of traditional farming systems suited to the ecological conditions of particular localities. The great bulk of farmers operate under these conditions today.

2. Science-based agricultural development during the present century which has transformed agriculture in many parts of the world. The industrialized nations have pioneered and excelled in this era.

3. Accelerated forced pace agricultural and rural development campaigns in developing countries, a thrust of recent origin. (1)

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1. Wortman, S and R.W. Cummings. To Feed This World: The Challenge and the Strategy. Baltimore: Johns Hopkins University Press. 1978.

Mosher, in his book, Getting Agriculture Moving, had identified the essential facilities and services required for agricultural development. (1)

These were:

* markets for farm products;
* local availability of supplies and equipment;
* production incentives;
* transportation, and
* constantly changing technology.

Without any of them, there can be no agricultural development. With all of them present, some development can take place.

Mosher also identified other elements which he called "accelerators", each of which is important, but not indispensable. There can be agricultural development without one or more of them.

But since many countries need as rapid agricultural development as possible, the presence of each of the accelerators can greatly assist.

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1. Mosher, A.T. Getting Agriculture Moving. New York: Agricultural Development Council. 1966. p 60.

He listed the accelerators as:

* education for development;
* production credit;
* group action by farmers;
* improving and expanding agricultural land; and
* national planning for agricultural development.

Agricultural research can contribute to development through economic growth and improved standards of living.

The primary outcome of agricultural research is new knowledge and/or materials and methods. Research knowledge used only as a basis for further studies is sometimes called basic research, and investigations which produce knowledge and/or materials and methods of direct utility in agricultural development are called applied research.

Historical Overview of Agricultural Research

In terms of history, it has to be assumed that the earliest civilisations made observations about their successes and failures in growing crops and animals.

Such conclusions must have contributed, perhaps in erratic, maybe unsystematic, and even haphazard ways, to improvements in agricultural production over time.

However, it was Sir Francis Bacon, (1561-1626), who established not only agricultural science, but indeed the whole scientific ethos. Bacon abandoned the idea of scholarly logic and deductive reasoning, and replaced it with an inductive process, from which truth could be discovered on the basis of empirical observation.

Brief comment will now be made about the beginnings of agricultural research in the industrialized world.

Agricultural Research in Great Britain

The formulation by Bacon of the scientific method, which incorporated the subsequent confirmation or negation of stated hypotheses, established the core of a new scientific experimental procedure. His studies were pursued on his farm, at St. Albans, England, and he elaborated his thesis in his classical work, Novum Organum, published in 1605. However, it took a long time for his ideas to be put into general practice. In fact, the first agricultural experiment station was established at Boussingault in Alsace, France, in 1834, where carefully planned field and laboratory experiments were undertaken on leguminous nitrogen.

In England, the first agricultural research centre was established at Rothamsted, in 1843, and financed personally by Sir J.B. Lawes throughout the nineteenth century. In this respect, Rothamsted reflected the English perspective of the day that agricultural improvements should be carried out by country gentlemen. The Edinburgh Laboratory, founded in 1842, was supported by the Agricultural Chemistry Association of Scotland, a volunteer agricultural society.

From that time, many attempts were made to apply modern chemical knowledge to farming, by scientists such as Lavoisier, Lawes and Gilbert. Subsequently, nascient agricultural science in Great Britain fell on hard times.

As far as agricultural education was concerned, studies began at the University of Oxford in 1880, and later at Wye and Cambridge, but agricultural science was not at the time considered a respectable field of study. These early traditions were not lost, however, since the Chemical Society continued to harbor the discipline of agricultural chemistry, and the Linnaen Society held a place for agricultural botany. (1)

Widespread debate about agriculture followed the address by Sir William Crookes to the British Association for the Advancement of Science in 1899 on "The Wheat Problem". He expressed concern about the likely decline in the supply of wheat to bread eaters in the developed world. (2) His comments stimulated further development in agricultural research and education.

In 1909, the British Government established a commission to fund and thereby foster agricultural research, which it felt might lift the country's agriculture out of doldrums that it was experiencing in the early part of the new century. This was the first step towards socialized agricultural research in that country. Even after this move, progress was slow.

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1. Russell, E.J. A History of Agricultural Science in Great Britain, 1620-1954. London: Allen and Unwin. 1966.

2. Crookes, W. The Wheat Problem. New York: Knickerbocker Press. 1899.

However, after the first professionally paid agricultural researchers were appointed in 1912, organized research got underway, and gradually a network of agricultural research stations was formed throughout the country.

Today, agricultural research in the United Kingdom is controlled by a council, whose primary aims are to advance scientific knowledge and to exploit this sort of knowledge to increase the efficiency of the agricultural, horticultural and food industries, and to safeguard and improve the quality of food for the community.

Agricultural Research in the United States

In the United States, the pattern of growth of agricultural science differed markedly to what had occurred in Great Britain.

There, it was the outbreak of the civil war that stimulated interest in Federally-funded agricultural activities. (1)

The Agricultural Society pressed for the formation of a Federal Department of Agriculture, while in the Congress, Justin S. Morrill, argued strongly for a land grant college Act. In the event, Abraham Lincoln backed a proposal for a bureau of agricultural statistics, later to become a department.

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1. Rossiter, M.W. The Emergence of Agricultural Science. New Haven, CI: Yale University Press.

The aim was:

> "to acquire and diffuse....useful information on subjects connected with agriculture in the most useful and comprehensive sense of the word, and to procure, propagate, and distribute among the people new and valuable seeds and plants." (1)

A commisioner for agriculture was empowered to gather information, by correspondence, by collecting statistics, or by:

> "practical and scientific experiments (accurate records of which experiments shall be kept in his office)." (2)

The Act also provided for a chief clerk and mentioned the service of:

> "chemists, botanists, entomologists, and other persons skilled in the natural sciences pertaining to agriculture." (3)

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1. Dupree, A.H. "The Evolution of Research in Agriculture" in Science in the Federal Government. Cambridge, MA: Belknap Press of Harvard University Press. 1957. p 149.

2. Dupree, A.H. Ibid. p 149.

3. Dupree, A.H. Ibid. p 149.

The Morrill Act of 1862 helped start agricultural science education in many state colleges. But not all, as Kearl recorded:

> "In many states (Wisconsin and Minnesota, for example) the Morrill lands were assigned to support the expansion of agriculture in a university already in existence. In others (among them, Iowa and Michigan) the lands went to broaden the scope of the existing agricultural college. In still others, (such as Illinois, Kentucky and Calfornia) the Morrill grant served as the agency to bring into being a new state university." (1)

At this time, there was not, of course, any backlog of agricultural information. But, in due course, it was not surprising to find that:

> "The farmer wanted to know what was best and most profitable in wheat, corn and livestock. He wanted to know how to control disease in plants and animals, how to feed both plants and animals to obtain better returns...The public often did not understand why there were no ready answers to questions." (2)

Another piece of landmark legislation in the United States helped to overcome such problems. This was the Hatch Act of 1885 which introduced Federal funds for agricultural research. Some states had already begun investigatory activities, but the new law financed the establishment of agricultural experiment stations in every state.

1.Kearl, B.E. "The Communication Function in American Land Grant Universities." Paper to the Indo-U.S. Subcommission on Education and Culture, Hyderabad, India, Jan. 1977.

2. Kearl, B.E., quoting from Eddy, E.D. Colleges for Our Land and Time.

> "It put into statutory form the obligation to report to the public what research was accomplishing. If a state accepted funds for scientific investigation and experiment respecting the principles and applications of agricultural practice, it accepted the duty to diffuse its findings. An annual report was required...free distribution of these reports was authorized through the postal service, and funds were allocated for publication and distribution." (1)

It was, however, well after the turn of the century before the new state agricultural experiment stations came to be regarded as productive sources of new knowledge, or significant contributors to the growth of productivity of agriculture in the United States. Further, it was not until 1914, with the passage of the Smith-Lever Act, that the cooperative extensive service came into being. Within a decade, the national agricultural research and extension system had been institutionalized.

Today, the results of agricultural research in the United States have been recognized as being a significant factor in the increased agricultural productivity of that country. (2)

Evenson, Waggoner and Ruttan have described the outcome in terms of the economic benefits of the long history of public research in agriculture:

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1. Kearl, B.E. Op.Cit. p 3

2. Hayami, Y. and V.W. Ruttan. Agricultural Development: An International Perspective. Baltimore: Johns Hopkins Press. 1971.

> "Agricultural productivity continues to grow. Annual rates of return on research expenditure are of the order of 50 per cent. Research oriented to science is profitable when associated with technological research. Decentralization, as in the system of state agricultural experiment stations and sub-stations, has allowed close association of research oriented to science with that oriented to technology and to farming." (1)

Agricultural Research in the Southern Hemisphere

In the case of the Southern Hemisphere, agricultural research is even more youthful than was the situation in Great Britain and the United States.

Research in agriculture was started at Lincoln College on the South Island of New Zealand in 1878. (2)

In Australia, the establishment of Roseworthy Agricultural College in South Australia in 1883 marked the start of formal, high level agricultural education in this country. The scientific agriculture tradition also began there when the first principal, J.D. Custance, introduced and tried new varieties of wheat, and experimented with superphosphate and other fertilisers. (3)

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1. Evenson, R.E., P.E. Waggoner and V.W. Ruttan. "Economic Benefits from Research: An Example from Agriculture." Science. 205: 1979. pp 1101-1107.

2. Blair, I.D. The Seed They Sowed. Centennial Story of Lincoln College. Christchurch: Whitcoulls. 1978.

3. Wadham, S.M. Australian Farming. Melbourne: Cheshire. 1965. p 29.

Agricultural research has been accorded a high place in Australia. Today, research in agriculture is undertaken by the Commonwealth Scientific and Industrial Research Organization, each of the six State Departments of Agriculture, the nine Faculties of Agriculture in Australian Universities, and a number of other organizations. Annual expenditure is estimated to approximate several hundred millions of dollars. This is a significant amount of money especially in view of the fact that the number of farm holdings in Australia is only 170,000.

This brief sketch of the beginnings of agricultural research in several First World countries serves to emphasize that, by many historical yardsticks, this endeavor is youthful: no more than 150 years in the Northern Hemisphere, and only 100 years in the Southern Hemisphere. (1)

Research on Tropical Agriculture

The successful tradition of agricultural research in the industrialized countries stands in startling contrast to what has occurred in other parts of the world, especially in the tropical regions. A popular lay image of the tropics has been one of a perpetual garden with abundant crops ripening in equatorial sunshine, and watered by plentiful rains. An agriculture, indeed, which would have little need to gain the benefits accruing from research. But, this picture is far from reality.

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1. Brien, J.P. ed. Agricultural Research Services in Australia. Canberra, A.C.T.: Department of Primary Industry. 1980.

In the period immediately after the Second World War, it became apparent that food production in the countries in these regions was generally low, and certainly not keeping pace with population growth. In fact, the majority of the world's hungry people, then and now, live in the tropics. At that time, there existed no substantial history of sustained agricultural research to improve productivity and technical efficiency of agricultural production for the benefit of these countries.

In many respects, in the so-called developing countries of the world, and in the old established civilizations of Asia, the Middle East and Latin America, agriculture virtually continued to be practiced in time-honored ways.

It is true that some serious scientific research in agriculture had occurred in a few places in the tropics from about the 1930s, but then only in connection with crops of export significance to the colonial powers then in existence.

The Imperial College of Tropical Agriculture in Trinidad, and the Dutch centre at Buitenzorg in Java, were examples of these research stations. Investigations were also undertaken on cotton in the Sudan, on rubber in Malaya, tea in Ceylon, and cocoa and bananas in Trinidad.

For a short time after the War, it seemed that the problems of agricultural development might be solved by the transfer of science and technology from the developed nations to the developing countries, but this soon proved to be unworkable. (1)

It began to become clear, that in addition to neglect in research, the complete scientific knowledge system in agriculture was virtually absent. Such a system had been established and honed to increasing perfection throughout more than 100 years in the developed countries of the world. As Bunting has stated:

> "Science grows and technology is developed in knowledge systems, the principal components of which are:
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> * the stock of accumulated knowledge in libraries and the minds and memories of people;
> * the means of extending this by acquiring new knowledge (research);
> * the means of preparing it for use on a practical scale (development);
> * devices for communicating knowledge, skills and technology, and for equipping people for them (extension, education and training);
> * the practical means of using or applying the knowledge or technology to particular practical purposes. (2)

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1. Rice. E.B. Extension in the Andes. Boston: Massachussetts Institute of Technology Press. 1974.

2. Bunting, A.H. Serving the Rural Poor: The Role of Science and Technology. New York: International Agricultural Development Service. 1979.

All of these elements are important. The impact of research alone will be constrained should the other elements be absent or unable to take up the new knowledge produced.

Beginnings of International Agricultural Research

An early demonstration of successful agricultural research in a developing country had been carried out by the private, philanthrophic Rockefeller Foundation, in conjunction with the Government of Mexico, in that country from 1943.

The work had been prompted by a visit two years before by an eminent scientific group comprising R. Bradfield of Cornell University, P.C. Mangelsdorf of Harvard University and E.C. Stakman of the University of Minnesota. The program was headed by J.G. Harrar, a plant pathologist, and involved research on basic food crops such as wheat, maize, potatoes and beans.

Concurrently, the scheme trained Mexicans to eventually take over the program.

By the early 1960s, much of the technology needed to improve Mexico's main crops had been developed within this research enterprise, and hundreds of Mexican personnel had been trained.

The success of the program, especially that on the development of dwarf wheat cultivars by N.E. Borlaug, encouraged the Rockefeller Foundation to establish similar programs in Colombia, Chile and India. (1)

Research on Rice

It was in the mid 1950s that the Rockefeller Foundation became interested in the possibility of establishing a rice research centre.

Rice is, among the major grain crops, the only one that is grown almost exclusively for human food.

It is the staple food crop for the heavily populated countries of south and southeast Asia, and, overall, constitutes half of the diet for half of the people of the world.

At the time, some rice research was being conducted in Japan, and at the Central Rice Research Institute at Cuttack, India.

But crop production worldwide was low and stagnant.

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1. Stakman, E.C., R. Bradfield, and P.C. Mangelsdorf. Campaigns Against Hunger. Cambridge, MA. Bellknap Press of Harvard University Press. 1967.

Rice is an annual grass belonging to the same family as barley, oats, rye and wheat.

The two cultivated rices, each with many varieties, are Oryza sativa of Asia, and Oryza glaberrima of West Africa. Domestication of O. sativa may have begun in Asia more than 7,000 years ago.

The plant has long grown in a diverse variety of environments, and over time, this cultivated species of Asia has differentiated into three sub-species based on geographic conditions: indica, japonica and javanica.

A further classification, highlighting the habitat in terms of soil and water, is irrigated and deepwater rice, and rain-fed upland and lowland rice.

In 1959, discussions began between the Rockefeller Foundation and another private organization, the Ford Foundation, concerning the possibility of establishing an international agricultural experiment station to be devoted to research on rice.

The rationale for such an institution, and the desirability of locating it in the Philippines, was conveyed in a Rockefeller Foundation paper.

Harrar, then head of agricultural sciences in the Rockefeller Foundation, wrote:

> "On the assumption that a significant social and scientific contribution could be made through the establishment of an International Rice Research Institute, consideration has been given to the most logical site for such an operation.
>
> For a number of reasons, it has been decided that the island of Luzon in the Philippine Islands is the most logical choice. Many of the reasons are obvious but others might be mentioned which include the fact that the Philippine Islands are an important rice producing area but one where the demand far outstrips the supply.
>
> Average production figures are low, management practices are primitive and opportunities for research, demonstration and extension are great.
>
> Further mnmore, the Philippine Islands has a progressive School of Agriculture located at Los Banos and this institution has had the benefit of a number of years of association with leading agricultural scientists from Cornell University under an ICA-College contract.
>
> There is in the Philippines an understanding of the need for greatly increased agricultural research and acceptance of the principle of international cooperation.
>
> Another asset is the fact that the Philippine Government has friendly relationships with essentially all the countries of Asia." (1)

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1. Harrar, J.G. Memorandum to Dean Rusk for F.F. Hill, Rockefeller Foundation, October 8, 1958.

An International Rice Research Institute

The concept of an International Rice Research Institute was considered further by the Rockefeller and Ford Foundations, in conjunction with the Government of the Philippines, during 1959, and a decision was made to proceed with its establishment. The Institute was to be located at Los Banos, in the Province of Laguna, in the Philippines, for nominal rental, on a piece of land belonging to the College of Agriculture of the University of the Philippines. Additional land for experimental purposes was purchased with funds amounting to $ 250,000 from the Ford Foundation. A sum of $ 185,000 was appropriated from the Rockefeller Foundation for establishment operations, and $ 6.9 million came from the Ford Foundation for construction of the Institute. (1)

The objectives of the new Institute were:

> " 1. To conduct basic research on the rice plant, on all phases of rice production, management, distribution and utilization with a view to attaining nutritive and economic advantage or benefit for the people of Asia and other major rice-growing areas through improvement in quality and quantity of rice;
>
> 2. To publish and disseminate research findings and recommendations of the Institute;
>
> 3. To distribute improved plant materials to regional centers where they might be of significant value or use in breeding or improvement programs;
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> 4. To develop and educate promising young scientists, primarily from South and Southeast Asia along lines connected with or related to rice production and utilization, through a resident training program under the guidance of well-trained and distinguished scientists;

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1. Ma, P.C. "Introducing the International Rice Research Institute". International Rice Commission Newsletter. IX : 2: June 1960. p. 29.

5. To establish, maintain and operate an information center and library which will provide interested scientists and scholars everywhere with a collection of the world's literature on rice; and

6. To organize or hold periodic conferences, forums and seminars, whether international, regional, local or otherwise for the purpose of discussing current problems." (1)

Scientific Research Begins at IRRI

The Institute was formally organized on April 14, 1960, and dedication ceremonies were held at the new Institute (IRRI) at Los Banos on February 7, 1962.

IRRI was the first truly international agricultural research center with its own independent Board of Trustees, and a scientific research staff recruited worldwide.(2)

Organizationally, IRRI reflected the institutional model formulated within the Colleges of Agriculture in the Land Grant Universities of the United States, where research and teaching in the component disciplines of agriculture was based on the respective plant, animal and social sciences.

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1. Articles of Incorporation of the International Rice Research Institute. From Chandler, R.F. An Adventure in Applied Science. A History of the International Rice Reserarch Institute. Los Banos: IRRI. 1982. p 196.

2. Chandler, R.F. Rice, Science and Man. Los Banos: IRRI. 1972. pp 1-17.

The first Director of IRRI, R.F. Chandler, recounted:

> "When the organizational framework for the Institute was developed in 1961-62, the IRRI administrators decided to create only eight departments: Varietal Improvement, Agronomy and Soils, Plant Protection; Plant Physiology; Chemistry; Agricultural Engineering; Statistics and Agricultural Economics. In addition, there would be the non-research professional units consisting of Library and Documentation Center, Experimental Farm, Food and Dormitory Services, Building and Grounds, and the administrative group comprising director, associate director, executive and treasurer." (1)

Scope of the Research Program

From the earliest time, scientists in the Varietal Improvement Department decided that the Institute's rice breeding program should be directed towards developing varieties that were short, stiff-strawed, and fertilizer responsive, that were photoperiod insensitive, and thus could be early maturing, and that were resistant to or at least tolerant of attacks by major insects and diseases. A rice germplasm collection was started together with a series of basic studies on rice genetics.

Each provided the basis for the rice breeding program, and critical though these were, the real impact of IRRI on world rice production came with the distribution of new rice varieties.

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1. Chandler, R.F. Ibid. p 50.

In 1962, varietal crosses were made between Peta, a tall Indonesian variety, widely grown in the Philippines, with the characteristics of vigor, seed dormancy, resistance to several insects and diseases, and Dee-geo-woo-gen, a high yielding, heavy tillering, short statured variety from Taiwan.

A new variety, stemming from this original work, produced outstanding yields of up to 8,236 kilograms per hectare, and was named IR8.

President F.M. Marcos of the Philippines inspected the variety in June 1966, and this resulted in the headline of the Manila Bulletin, "Marcos Gets Miracle Rice". The term "miracle rice" immediately captured attention. IR8 was available for distribution in November of that year, and by 1968, it was estimated that some $ 300 m. was added to the annual harvest resulting from the use of this new variety. (1)

In the early years, the Plant Physiology Department was involved in studying the characteristics of some of the parental types in order to understand better the morphological distinctions and physiological processes related to yield capacity.

Scientists in the Agronomy Department were interested in maximum yields attainable, fertility, water management, and multiple cropping studies.

1. Chandler, R.F. Ibid. p 109.

The Soil Chemistry Department made fundamental studies on the chemistry of flooded soils.

Soil Microbiology had three principal interests: the interactions between rice roots and micro-organisms in the rhizophere, nitrogen transformations in submerged soils, and pesticide residues.

Plant Pathology, in the early years, tested varieties from the Institute's collection for resistance to rice blast disease, and other fungal, viral and bacterial diseases.

Entomologists were interested in the control of rice stem borers, green leafhoppers and the brown planthopper.

Agricultural engineers, during the early years, worked principally on testing and modifying equipment for wetland preparation.

Other research was concerned with changing the design of a comb thresher, measuring irrigation water use and losses, and studying the relationships between spacing and yield components.

The research in the Chemistry Department comprised work in Biochemistry and Cereal Chemistry.

In the former area, early, basic research was concentrated on studying the nature of the enzymatic mechanism of starch formation in ripening rice grains and the characteristics and changes of Fraction 1 protein in the rice plant.

Studies by cereal chemists, on the other hand, were focussed on the physicochemical properties of the rice grain through investigations on the composition of proteins and starch, thereby relating the chemical properties of rice to eating, and cooking qualities, and nutritional value.

Agricultural Economics was concerned with an economic analysis of insecticide experiments, comparing the impact of yield per hectare and area planted on rice production in Southeast Asia, and determining the implications of rice marketing and pricing policies in Southeast Asia.

The significance of IRRI's research have been couched in these terms:

> "The success of the high-yielding rice from IRRI has been crucial for Asia where more than half of the world's people live, and 92 per cent.of the world's rice is grown.

> Worldwide, rice provides more than half of the total calories for at least one third of the world's people, whose lives depend on the annual rice cycle. For them, an abundance of rice means life; a scarcity of rice means hunger and malnutrition, even starvation." (1)

Successful Rice Research

More than 30 per cent of the world's rice land is now planted to IRRI-bred varieties of rice. IR8 was succeeded by many other new and improved varieties of rice.

IR36, for example, an early-maturing, high yielding insect and disease resistant rice variety has become the most widely grown variety of any food crop the world has known. Almost 11 m. hectares of IR36 are now planted worldwide. Some 60-65 per cent. of all rice grown in many of the countries in Southeast Asia is now planted with IR36.

It is estimated that Asian farmers harvest an additional five million tons of rice each year, and gain more than $ 1 b. extra income because they plant IR36.

Its insect resistant qualities save nearly $ 0.5 b. in insecticide costs each year. (2)

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1. Consultative Group on International Agricultural Research. Washington, D.C. 1980. p 43.

2. IR36. The World's Most Popular Rice. Los Banos: IRRI. 1983

The International Agricultural Research System

IRRI became the prototype institution for a group of agricultural research institutes which have emerged over the past 20 years, and which are called the International Agricultural Research Centers (IARCs).

In addition to IRRI, there are now 12 other institutes, as follows:

CIAT: Centro Internacional de Agricultura Tropical, Cali, Colombia.

CIMMYT: Centro Internacional de Mejoramiento de Maiz y Trigo, Londres, Mexico.

CIP: Centro Internacional de la Papa, Lima, Peru.

IGPGR: International Board for Plant Genetic Resources, Rome, Italy.

ICARDA: International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

ICRISAT: International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India.

IFPRI: International Food Policy Research Institute, Washington DC, USA.

IITA: International Institute of Tropical Agriculture, Ibadan, Nigeria.

ILCA: International Livestock Center for Africa, Addis Ababa, Ethiopia.

ILRAD: International Laboratory for Research on Animal Diseases, Nairobi, Kenya.

ISNAR: International Center for National Agricultural Research, The Hague, Netherlands.

WARDA: West Africa Rice Development Association, Monrovia, Liberia.

The international agricultural research institutes, listed above, present certain common characteristics.

As Pinstrup-Andersen has noted:

> "An international agricultural research institute is an institute established and financed by donor agencies in close collaboration with the host country of the institute. Even though the institute is international the majority of its activities is usually carried out in a single country - in most cases a developing country.
>
> Normally, the land required for the individual institute is made available by the host country free of charge or at nominal costs.
>
> The composition of the research staff is determined by the research priorities and the qualifications of the individual researcher, with little or no regard to nationality.
> Each of the institutes is dedicated to the solution of serious agricultural production problems within developing countries.
>
> Typically, these problems are identified by a committee prior to the establishment of the institute. Each committee is composed of the best available experts at the international level. The interests of governments of the developing countries are considered in this initial priority setting. Once the institute is established, periodic assessments and revisions of research priorities are carried out." (1)

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1. Pinstrup-Andersen, P. Agricultural Research and Technology in Economic Development. London: Longman. 1982. p 89.

International agricultural research, which leads to increases in agricultural production, results from the integration of knowledge derived from scientific research. Such research can be classified in the following ways:

* Basic research which is designed to develop new understanding;
* Strategic research which aims at the solution of specific problems;
* Applied research which sets out to create new technology; and
* Adaptive research which aims to adjust technology to a particular set of environmental conditions.

While the original purpose of the international research institutes was to generate new technology (i.e. to concentrate on applied research), the generation of new technology requires the provision of results from strategic research, and, in turn, the results from basic research.

<u>The Consultative Group on International Agricultural Research</u>

The Consultative Group on International Agricultural Research (CGIAR) is the transnational funding framework for the IARCs. This body was formed in 1971 by the Food and Agriculture Organization of the United Nations, The United Nations Development Program, and the International Bank for Reconstruction and Development (The World Bank).

The CGIAR acts on behalf of a consortium of donors ranging from multinational organizations and national governments to private foundations. Its headquarters are in Washington D.C., USA. The CGIAR is advised by a Technical Advisory Committee, comprising a group of eminent scientists from the industrial nations and the developing countries. It is headquartered in Rome, Italy.

In 1983, some U.S. $ 163 m. was contributed to the CGIAR for research in the international agricultural research centres. This is a relatively small amount when considered in terms of total world expenditure on agricultural research, which has been estimated to be of the order of U.S. $ 7 b. (1)

Viewed globally, more than 7,000 staff members, including some 600 senior scientists from more than 40 countries are engaged in research in the various institutes The research focus is on crops, livestock and farming systems, which yield three quarters of the total food supply of developing countries.

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1. Schultz, T.W. The Economics of Research and Agricultural Productivity. New York: International Agricultural Development Service. 1979.

As the international agricultural research system completes the first quarter century of its existence, there is emerging a tripartite institutional arrangement involving the agricultural research bodies based in the industrialized world, and the research systems of developing countries, together with the international institutes themselves in a cooperative endeavor to boost agricultural production and thereby lift the living standards of people living the developing nations. (1)

Summary of Chapter

Chapter 4 pointed to the place of research in agricultural development and noted the success of this activity in the industrialized countries over the past 150 years. Agricultural research is of recent origin in the developing countries of the world.

Two private bodies, the Ford and Rockefeller Foundations, in conjunction with the Philippine Government, established the International Rice Research Institute, adjacent to the University of the Philippines at Los Banos, 65 km. south east of Manila in 1960. Its objective was to improve the quantity and quality of rice.

In 1966, it released a new cultivar, IR 8, which spearheaded the green revolution in rice growing regions of the world. Other improved cultivars have followed in the years since.

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1. The Fragile Web. The International Agricultural Research System. IDRC: Ottawa, Canada. 1983.

The success of IRRI led to the development of the international agricultural research system, which now comprises some 13 institutes. Funding is provided through the transnational Consultative Group on International Agricultural Research.

This network is responsible for the generation of scientific and technological information from agricultural research.

CHAPTER 5

A STUDY OF FORMAL SCIENTIFIC COMMUNICATIONS FROM THE INTERNATIONAL RICE RESEARCH INSTITUTE

"Modern agriculture would be impossible were it not for advances in scientific knowledge. From an economic point of view, this knowledge, when it becomes transformed into inputs, techniques and into the skills of man, is the most important factor in production."

(Schultz, 1972)

System Perspective of an Agricultural Research Station

An important assumption in the establishment of the International Rice Research Institute, was that, in due time, following the appointment of a critical number of senior scientific staff, and the conduct of a suitable research program, scientific results would be forthcoming, and these would be conveyed to appropriate audiences. The ultimate aim, as noted, would be that useful scientific and technological information in the rice sciences generated by Institute scientists would be available to benefit rice farmers in the developing nations of the world.

In this respect, the scientific activities of the Institute, would, typically, mirror the system perspective of an agricultural experiment station in a first world country, as outlined by Blaise and Paulsen.

> "In (these) research stations, (the) three outputs are information, influence, and investment in future capacity. In the long run, only information outputs of research institutions can justify their use of public resources...
>
> The output in an experiment station is the information it generates and releases - its formal and most visible output. It includes research papers, reports, bulletins, press releases, questions answered and consultations given.
>
> These packages of information flow through delivery systems to users, and if applied, affect beneficiaries.

All productive research is similar in that it contributes to society by providing new understanding that widens the range of choice, increases the options, or reduces resource restraints.

Society accomplishes many of its goals through research. Other actions and investments also can accomplish social goals, but not by generating information." (1)

Objectives of the Institute

The specific objectives of the International Rice Research Institute were stated in formal legal terms in the Articles of Incorporation of the Institute, as follows:

"That the purpose of the corporation is to establish, maintain and operate an international rice research institute designed to pursue any and/or all of the following objectives:

1) To conduct basic research on the rice plant, on all phases of rice production, management, distribution, and utilization with a view to attaining nutritive and economic advantage or benefit for the people of Asia and other major rice-growing areas through improvement in quality and quantity of rice;

2) To publish and disseminate research findings and recommendations of the Institute;

3) To distribute improved plant materials to regional and international research centers where they might be of significant value or use in breeding or improvement programs;

4) To develop and educate promising young scientists, primarily from South and Southeast Asia along lines connected with or relating to rice production, distribution and utilization, through a resident training program under the guidance of well-trained and distinguished scientists;

5) To establish, maintain and operate an information center and library which will provide, among others, for interested scientists and scholars everywhere a collection of the world's literature on rice;

6) To organize and hold periodical conferences, forums and seminars, whether international, regional, local, or otherwise, for the purpose of discussing current problems. (1)

From this statement, it is clear that the "founding fathers" of the International Rice Research Institute intended that considerable emphasis would be placed in this new agricultural experiment station on the generation and communication of the findings from the research conducted by its scientists.

Organizational Pattern

The precise areas where research was to be initially pursued were outlined when the program committee of the new Institute convened its first meeting early in 1960. An organizational pattern was identified, with the following research programs:

" Production

1) Plant Genetics and Breeding, including plant genetics, plant breeding, taxonomy, morphology, cytology, preservation and distribution of genetic stock, method of experimentation, seed technology, etc.;

2) Soil Science and Agronomy, including soil chemistry, soil physics, soil management, fertilizer requirement, cultural practice, water management, crop rotation, etc.;

3) Plant Protection, including plant pathgology, entomology, microbiology, chemical control, biological control, weed control, etc.;

4) Plant Physiology, including plant physiology, metereology, (especially microclimatic studies) etc.;

---

1. Blaise, M.G. and Paulsen, A. "The Agricultural Experiment Station. An Institutional Perspective." Agricultural Sciences Review. Second Quarter. 1972. pp 11-17.

Utilization

1) Utililzation, including utilization, storage, preservation, etc.;

2) Processing of rice products and byproducts, including chemical and engineering aspects of processing, etc.;

Production and Utilization

1) Chemistry, including chemistry, biochemistry, food technology, utilization, chemical aspect of the processing of rice products and byproducts, etc.;

2) Agricultural Engineering, including farm implements, farm mechanization, irrigation and drainage, utilization, engineering aspect of the processing of rice products and byproducts, etc.;

Economics

1) Agricultural Economics, including agricultural economics, marketing, statistics, etc.;

2) Farm Management, including farm management, production cost, etc.;

Information

Including library, documentation, publication, collection and dissemination of information, printing, etc." (1)

---

1. Chandler, R.F. Op. Cit. p 205.

In accord with this organizational and research pattern, the committee suggested that "senior research scientists of the following subject matters" could be recruited as the program developed: plant breeder; plant geneticist; plant taxonomist or cytogeneticist; plant pathologist; entomologist; soil chemist; soil physicist; agronomist; agricultural engineer; biochemist; agricultural chemist (processing); agricultural economist; farm management specialist; and information officer. (1)

The initial eight research departments within the Institute were: Varietal Improvement; Agronomy and Soils; Plant Protection; Plant Physiology; Chemistry; Agricultural Engineering; Statistics; and Agricultural Economics. (2)

This, then, was the basis of the rice science knowledge generation system initially established at the International Rice Research Institute.

Aims of the Rice Science Communication Investigation

It is obvious that the production of scientific and technological information figured prominently from the outset in both the planning for the Institute, and the implementation of those plans in its establishment.

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1. Chandler, R.F. Op. Cit. p 206.

1. Chandler, R.F. Op. Cit. p 50.

Consequently, publication of scientific results was listed as a priority for all the research scientists, and the first Annual Report of the new Institute was able to list a series of papers and reports which had either reached publication or were in press.

All subsequent Annual Reports issued by the Institute have also featured this activity. As such, these Institute publications (1) have formed a part, albeit a significant part, of the overall communication activities of Institute scientists.

The formal rice science communications emanating from the Institute provided the data for the present investigation on the utilization of international agricultural science knowledge.

The output of publications from the Institute, particularly that produced through the first 20 years of its existence, was subjected to an extensive bibliographic analysis.

The general objective of the study was to achieve an understanding of the formal scientific communication network formed through publications - papers, monographs, reports, and the like - prepared by scientists who undertook research at the Institute, and to clarify the nature of the subsequent utilization of rice science knowledge.

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1. The word publication will be used hence, to indicate, equivalently, a research article, research report, scientific book, etc.

The particular research hypotheses developed for the principal investigation were as as outlined below.

1) That the formal rice science communications, which emanated from the Institute, constituted part of a normal scientific communication system.

2) That the nature of the information in the formal communication network beginning from the Institute demonstrated a bias towards more basic science rather than applied science.

3) That, in later contributions to rice science knowledge, the scientist-authors portrayed a propensity to employ the earlier Institute- generated information as "tools of persuasion" in reporting on their own studies in rice science.

4) That the diffusion of rice science information can be viewed in both temporal and spatial dimensions, on the basis of citations to original publications.

<u>Productivity of Scientific Publications</u>

The research study began with the preparation of lists of papers, monographs, reports, etc., published by scientists of the Institute from its inception until the end of 1979.

The period spanned the time from the establishment of the Institute through its formative years, and on to the end of the 1970s.

To gather this data, all the Annual Reports issued by the Institute during this period were carefully examined, and the appropriate appendices containing the official listings of the publications prepared by the scientists were noted.

The numbers of these publications were counted to provide the measure of of scientific publication productivity.

It should again be noted that, in making these counts, no distinction was made between different types of publication, or differences as to their size.

Table 5 shows the number of scientific publications prepared by scientists at the International Rice Research Institute each year for the period from 1963 to 1979.

TABLE 5

ANNUAL PRODCTION OF IRRI SCIENTIFIC PUBLICATIONS

Year	Number of Publications
1963	22
1964	36
1965	47
1966	62
1967	64
1968	43
1969	56
1970	44
1971	57
1972	60
1973	69
1974	71
1975	92
1976	71
1977	199
1978	146
1979	228

The total number of publications produced in the period under study was 1,367, and Table 6 shows the cumulative growth in scientific publication productivity at the Institute over the same period.

These scientific publications was authored or coauthored by some 351 scientists.

Mean productivity was, thus, 3.90 publications per scientist-author.

However, when the total authorship of publications produced during the period was analyzed further, it was found that the distribution was highly skewed.

A total of 192 scientists authored or coauthored one publication, and another 66 scientists authored or coauthored two publications each.

In other words, a total of 258 scientists - 18.8 per cent of the population - produced either one or two publications each.

At the other end of the scale, in terms of formal communications, there were some extremely productive scientists.

One scientist authored or coauthored a total of 87 publications.

A second scientist authored or coauthored 62 publications.

TABLE 6

CUMULATIVE GROWTH IN NUMBERS OF SCIENTIFIC PUBLICATIONS

Year	Total Number
1963	22
1964	58
1965	105
1966	167
1967	231
1968	274
1969	330
1970	374
1971	431
1972	491
1973	560
1974	631
1975	723
1976	794
1977	993
1978	1,193
1979	1,367

Two others authored or coauthored 56 publications each.

Just over one half of the publications - 51.7 per cent - were written by 6.8 per cent. of the total population of scientists.

In each of the above calculations, identified authors were the first named.

It should be recognized that, as noted earlier, that these assessments of scientific publication productivity are simply numerical counts: they do not attempt to measure any qualitative dimension.

Table 7 shows the distribution of authorship of the scientific publications produced during the period under study.

The Table shows that a small number of high producers of publications accounted for as about as many publications as a large number of low producers.

In fact, it was calculated that the square root of the total number of producers (approximately 19) wrote close to half (some 45 per cent.) of all the publications.

TABLE 7

DISTRIBUTION OF SCIENTIFIC AUTHORSHIP

Number of Publications Per Senior Author	Number of Senior Authors
1	192
2	66
3	24
4	14
5	11
6	8
7	3
8	2
9	4
10	1
11	2
12	3
13	2
16	1
17	1
18	2
19	1
20	3
21	1
26	1
28	1
32	1
36	1
41	1
54	1
56	2
62	1
87	1

This relationship was very similar to that postulated by Price who said:

> "If one computes the total production of those who write √n papers, it emerges that the large number of low producers account for about as much as the smaller number of large producers." (1)

Price reported that the inverse-square root law has held true for the early journals of the seventeenth century through to the present, and in several scientific disciplines.

This confirmation of the Price Law, together with the skewness of scientific publication productivity, is direct evidence of the existence of a standard scientific communication system.

The sample of publications therefore exemplifies a normal pattern.

These findings lend support to the first hypothesis of the research investigation.

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1. Price, D. deS. Little Science, Big Science. New York: Columbia University Press 1963.

The second part of the study involved a citation analysis of the publications produced by Institute scientists from the beginning through to 1979.

This was done by a manual search of the Science Citation Index, using the five-year cumulations, 1964-69, 1970-74 and 1975-79.

The manual search, rather than a computer scan, was preferred for the operation since occasional misspellings of the names of authors, inaccurate listings of authors, and errors in bibliographic details, were detected.

The procedure permitted these items to be taken into account in reviewing the data gathered for analysis.

A majority of publications in the total sample of 1,367 received no citations, and those which were cited, received very few.

In fact, only 86 publications received 10 or more citations each. These were then tabulated by deciles. Some 51 publications received between 10 and 19 citations each; 17 received between 20 and 29; 7 received between 30 and 39 each; 7 received between 40 and 49 each; 1 received between 50 and 59; 2 received between 60 and 69 each; and another 1 between 70 and 79.

The distribution of citations accorded the publications prepared at the Institute in the period under study are shown in the Table 8 on the following page.

TABLE 8

DISTRIBUTION OF CITATIONS BY PUBLICATIONS

Numbers of Citations	Numbers of Publications
10-19	51
20-29	17
30-39	7
40-49	7
50-59	1
60-69	2
70-79	1

<u>The Citation Analysis Publication Sample</u>

Of the scientific publications which scored 10 or more citations each, special attention was directed to those publications which had received 30 or more citations each, since, clearly, this group must have possessed very valuable information of particular importance to other scientists.

By definition, items of information contained in the publications was "utilized" by the subsequent citing authors.

A total of 18 publications fell into this category, with the number of citations per publication varying from 30 up to 76.

Half of this sample of very highly cited publications produced in the period through to 1979 were further randomly selected for detailed citation analysis.

The nine publications, which were located in the Library of Macquarie University, received a total of 434 citations.

On the following pages, bibliographic details of these selected publications together with other information, including, where appropriate, abstracts, summaries or introductions, is provided so as to make clear the content of the publications selected forstudy in this research investigation.

Akazawa, T., T. Minamikawa, and T. Murata.

"Enzymic Mechanism of Starch Synthesis in Ripening Rice Grains."

Plant Physiology. 39: 1964: pp 371-378.

Publication referred to as Akazawa 1964.

Number of Citations received: 48.

Summary:

Starch granules catalyzing starch synthesis were prepared from ripening rice grains. Starch synthesis was confirmed by both the enzymic assay for uridine diphosphate liberated during the transglucosylase reaction and the glucose-C 14 transfer to starch molecules from uridine diphosphate glucose-C 14. Glucose C 14 was incorporated into both the amylose and amylopectin fractions of the starch molecules.

A measurable amount of glucose-C 14 was transferred from sucrose- C 14 to starch in the presence of starch granules, sucrose synthetase and uridine diphosphate glucose. Glucose-C 14 was incorporated from sucrose into both the amylose and the amylopectin fractions of the starch molecules in much the same ratio as that obtained from uridine diphosphate glucose -C 14.

A crude enzyme preparation catylyzing sucrose synthesis was also found to have uridine diphosphate glucose pyrophosphorylase and uridine diphosphate glucose pyrophosphorylase and uridine diphosphate phosphokinase activities, indicating the existence in rice grains of a mechanism for uridine diphosphate glucose formation from glucose-1-phosphate.

The crude rice grain extract also exhibited strong hexokinase activity. Fructose-6-phosphate, glucose-6-phosphate, and glucose-1-phosphate were formed when sucrose utilization was combined with the hexokinase reaction.

Baun, L.C. E.P. Palmiano, C.M. Perez, and B.O. Juliano.

"Enzymes of Starch Metabolism in the Developing Rice Grain."

Plant Physiology. 46: 1970: pp 429-434.

Publication referred to as Baun 1970.

Number of Citations Received: 30.

Abstract:

The levels of starch, soluble sugars, protein, and enzymes involved in starch metabolism, α-amylose, β-amylose, phosporylase, Q-enzyme, R-enzyme, and starch synthetase were assayed in dehulled developing rice grains (Oryza sativa L., variety IR-8). Phosphorylase, Q-enzyme, and R-enzyme had peak activities 10 days after flowering, whereas α- and β- amylases had maximal activities 14 days after flowering.

Starch synthetase bound to the starch granule increased in activity up to 21 days after flowering. These enzymes (except the starch synthetases) were also detected by polyacrylamide gel electrophoresis. The activity in grains at the mid-milky stage (8-10 days after flowering) was determined in five pairs of lines with low and high amylose content in different crosses. The samples had similar levels of amylases, phosphorylase, R-enzyme, and Q-enzyme.

The samples consistently differed in their levels of starch synthetase bound to the starch granule, which was proportional to amylose content. Granule-bound starch synthetase may be responsible for the integrity of amylose in the developing starch granule.

Juliano, B.O. and J.E. Varner.

"Enzymic Degradation of Starch Granules in the Cotyledons of Germinating Peas."

Plant Physiology. 44: 1969. pp 886-882.

Publication referred to as Juliano 1969.

Number of Citations received: 46.

Abstract:

Starch, total α- and β-amylase, and phosphorylase levels and the zymogram patterns of these 3 starch-degrading enzymes were determined in the cotyledons of smooth pea (Pisum sativum L.) during the first 15 days of germination.

Starch is degraded slowly in the first 6 days; during this time α-amylase is very low, β-amylase is present at a constant level while phosphorylase gradually increases and reaches a peak on the fifth day. Beginning on the sixth day there is a more rapid degradation of starch which coincides with α-amylose production. One phosphorylase band and 2 β-amylase bands are present in the zymogram of the imbibed cotyledon. An additional phosphoryase band and 1α-amylase band appear during germination. Seeds imbibed in benzyladenine, chloramphenicol, and in cycloheximide show retarded growth and slower starch degradation and enzyme production than the controls.

We conclude that α-amylase is the major enzyme involved in the initial degradation of starch into more soluble forms while phosphorylase and β-amylase assist in the further conversion into free sugars.

Mendiola, L. and T. Akazawa.

"Partial Purification of the Enzymic Nature of Fraction 1 Protein of Rice Leaves."

Biochemistry. 3: 1964. pp 174-179.

Publication referred to as Mendiola 1964.

Number of Citations received: 35.

Abstract:

The major protein component of rice leaves was partially purified by extraction of the leaf proteins and gel filtration of the extracts on Sephadex columns.

This protein was characterized by starch-gel electrophoresis as the predominant protein band, and in the purified preparation was the only protein component discernible. The isolated protein preparation is believed to be identical to fraction 1 protein as studied by others. The fixation of $^{14}CO_2$ using ribose 5-phosphate as substrate in the system was definitely catalyzed by the isolated protein fraction.

The main product of the $^{14}CO_2$ fixation was 3-phosphoglyceric acid.

The three enzymatic activities involved in the system, namely phosphoriboisomerase, phosphoribulokinase, and ribose 1,5-diphosphate carboxylase, are believed to be associated with the fraction 1 protein of rice leaves.

McRae, I.C., K. Raghu and T.F. Castro.

"Persistence and Biodegradation of Four Common Isomers of Benzene Hexachloride in Submerged Soils."

Journal of Agricultural and Food Chemistry. 15. 1967. pp 911-914.

Publication referred to as McRae 1967.

Number of Citations received: 35

Abstract:

The persistence of the γ-isomer of benzene hexachloride (lindane) when added to submerged tropical soils at a rate approximately three times that recommended for the protection of rice from stem borer infestation and of the α, β and Δ isomers of benzene hexachloride applied at similar rates was between 70 and 90 days. Losses of all four isomers from sterilized, flooded soil samples were much slower than from nonsterilized samples, indicating that the microflora of submerged soils is able to degrade benzene hexachloride.

Microbial degradation of Δ-BHC was demonstrated by the release of $^{14}CO_2$ from submerged soils treated with ^{14}C labelled δ-BHC. An application of γ-BHC at a rate approximately five times the usual field rate apparently inhibited CO_2 evolution from two tropical soils.

Ou, S.H.

<u>Rice Diseases.</u>

Commonwealth Mychological Institute, Kew, England. 1972.

Publication referred to as <u>Ou 1972</u>.

Number of Citations Received: 46.

Preface:

In spite of the fact that most rice is grown in the tropics, relatively little work has been done on rice disease problems in tropical areas. The recent acute nature of the food problem has, however, stimulated an increasing number of people in the rice-growing countries in the tropics to conduct research and develop control measures.

The literature on rice diseases, unfortunately, has been very scattered and much of it has been unavailable to many tropical research workers.... The rapid accumulation of literature on rice diseases in more and more journal during the past 20 years has greatly worsened the situation... We have often been requested to supply 'all relevant literature' on a common disease such as blast or bacterial blight. Requests of this type are often difficult to comply with. Many rice workers in several tropical countries cannot identify such a disease as bacterial blight or distinguish leaf spot caused by blast from brown spot.

We feel there is at present a great need for a comprehensive reference book on rice diseases, written in a commonly used language, for students in both research and extension work in rice pathology. This book is aimed primarily at presenting the status of knowledge at this moment on each of the rice diseases known. The survey of literature has been made as complete as possible. Various views on a given subject are presented even though some of them are controversial and a few are of doubtful accuracy.Extensive relevant literature is cited in which researchers may look for further specific details.

Ponnamperuma, F.N.

"The Chemistry of Submerged Soils."

Advances in Agronomy. 24: 1972. pp 19-96.

Publication referred to as Ponnamperuma 1972.

Number of Citations received: 76.

Abstract:

Submerged soils have a low redox potential and a neutral pH.

Oxygen, nitrate, and sulfate are absent; carbon dioxide, ammonium, and sulfide are present.

Iron, manganese, and phosphorous become soluble.

The decomposition of organic matter produces an array of transitory substances ending as carbon dioxide, methane and humus.

Yoshida, S.

"Physiological Aspects of Grain Yield."

Annual Review of Plant Physiology. 23: 1972. pp 437-464.

Publication referred to as Yoshida, S. 1972.

Number of Citations received: 60

Introduction:

A high grain yield of any crop can be achieved only when a proper combination of variety, environment and agronomic practices is obtained. Understaning the physiological processes involved in grain production, such as vegetative growth, formation of staorage organs, and grain filling, helps determine the best combination of the above three factors, and also suggests what improvements can can be made to achieve a further increase in grain yield under a given condition.

Most physiological processes may be studied best in single plants in a controlled environment.

Crop production, however, usually occurs in a community in which the plants differ in many ways from single plants, and under a variable environment. Crop species also differ from each other in their morphological and physiological characters, so they differ in their response to the environment.

For these reasons, analysis of cause and effect relationship in crop grain yield is extremely complex. In this review, I use rice to illustrate most points because of my familiarity with this crop.

At the same time, physiological similarities and dissimilarities of rice and other grain crops are examined. In the past, several excellent discussions were attempted on physiological aspects of grain yield, and the reader is advised to refer to these articles.

Yoshida, T. and R.R. Ancajas.

"Nitrogen Fixation by Bacteria in the Root Zone of Rice."

Soil Science Society of America Proceedings. 35: 1971. pp 156-157.

Publication referred to as Yoshida, T. 1971.

Number of Citations received: 51

Abstract:

Atmospheric nitrogen is fixed in the root zone of rice plants (Oryza sativa L.)

Acetylene-ethylene assay showed that bacteria, rather than the root tissues, do the fixation.

Although the root tissues produce a trace of ethylene, they cannot reduce acetylene to ethylene. The apparent Km (Michaelis constant) of acetylene was much higher than values from known nitrogen fixing bacteria.

It will have been noted that the sample of scientific publications being studied, and which were published between 1964 and 1972, comprised several research papers, two major literature reviews, and a book.

The major publication carrying the scientific research papers was Plant Physiology, published by the American Society of Plant Physiologists. This periodical carried three papers.

Other publications represented were the Journal of Agricultural and Food Chemistry, published by the American Chemical Society, Advances in Agronomy, published by Academic Press in co-operation with the American Society of Agronomy, Biochemistry, published by the American Society of Biochemists, and the Soil Science Society of America Proceedings.

The book on Rice Diseases was published by the Commonwealth Mychological Institute of England.

The sample of Institute publications selected for analysis ranged in size from five to several hundred pages long, and, with the exception of two items, all were multiple-authored.

The disciplinary affiliation of the principal authors is shown in Table 9.

TABLE 9

DISCIPLINARY AFFILIATION OF PRINCIPAL AUTHORS

Discipline	Publication
Biochemistry	Akazawa 1964 Mendiola 1964
Chemistry	Baun 1970 Juliano 1969
Plant Pathology	Ou 1972
Plant Physiology	Yoshida, S 1972
Soil Chemistry	Ponnamperuma 1972
Soil Microbiology	McRae 1967 Yoshida, T 1971

Citation Rates for Selected Publications

The next stage of the analysis focussed on the annual citation rate for each of the selected publications written by the Institute scientists.

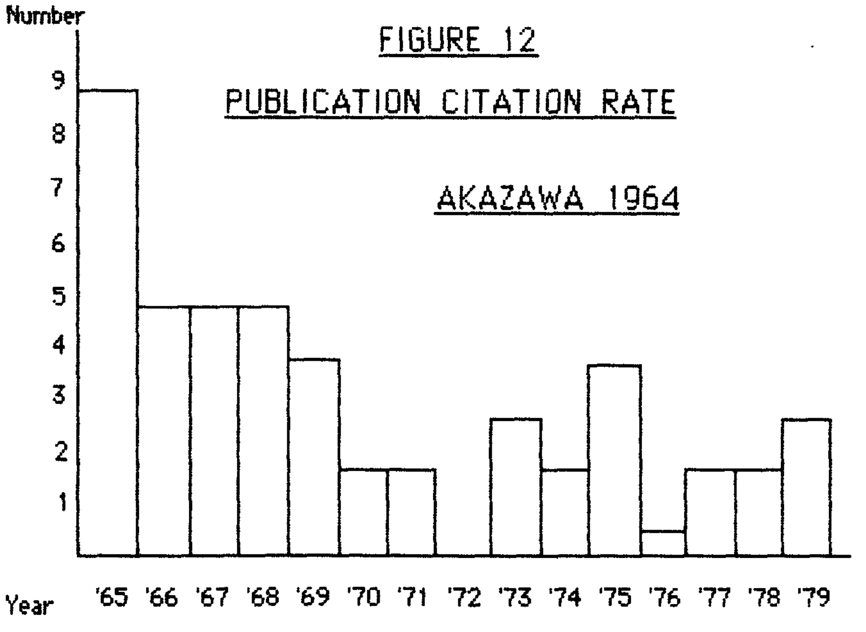
This particular part of the investigation involved taking each specific publication, and using the Science Citation Index, calculating the number of citations each was accorded year by year.

This was done for the period from the appearance of the publication through to the end of 1979.

This meant that for some publications, (e.g. Akazawa 1964 and Mendiola 1964), the citations covered the whole period of study.

In other cases, for example, Ou 1972 and Ponnamperuma 1972, the available citation period covered only the last part of the period under study.

The results of this bibliometric investigation are graphed and described on the following pages.



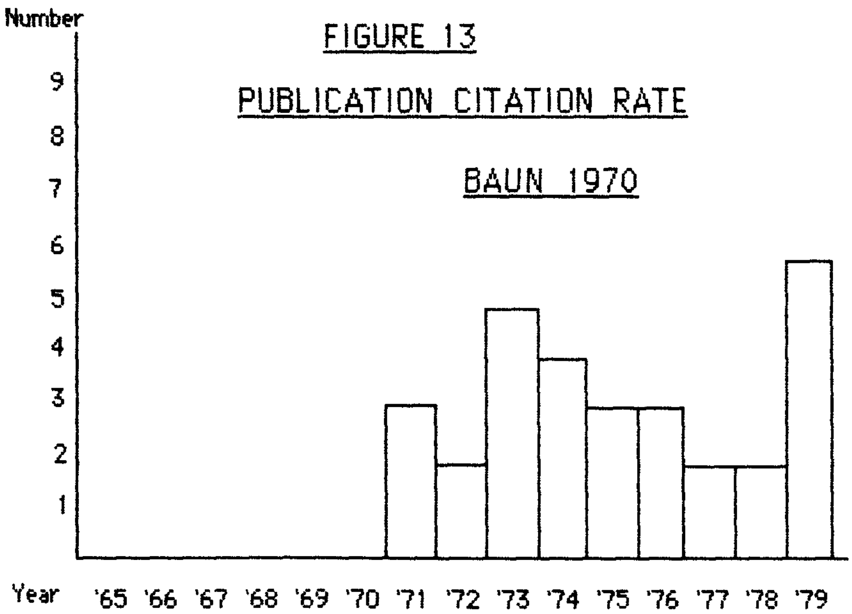
This paper received its highest number of citations in the first year after its appearance. In terms of citation rate, it peaked early in the cycle.

Subsequently, over several years, it received, in each year, about half the citations it received in the first year. From then on a moderate, but erratic, annual rate remained for the rest of the period.

FIGURE 13

PUBLICATION CITATION RATE

BAUN 1970



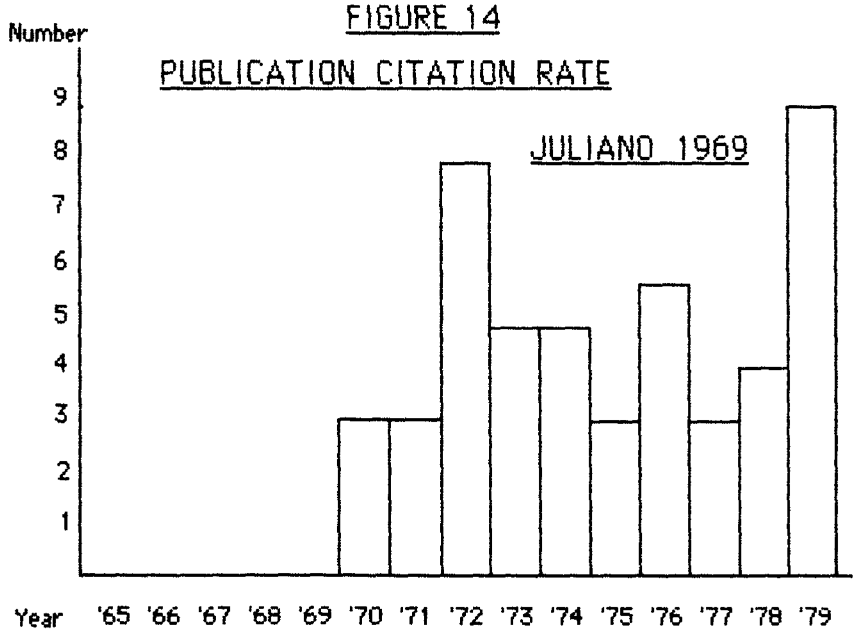
In this case, the publication achieved a moderately high rate of citation in the first year of its appearance.

One peak occured two years after its appearance, and then the rate slowed until this was superseded with the highest number of citations being recorded in the final year of the period under study.

FIGURE 14

PUBLICATION CITATION RATE

JULIANO 1969



The Juliano1969 paper gained a moderately high citation rate in the first two years after its appearance and continued on, with two exceptional years, the third, and the tenth, after its appearance.

This citation pattern is similar to that which occurred with Baun 1970 paper.

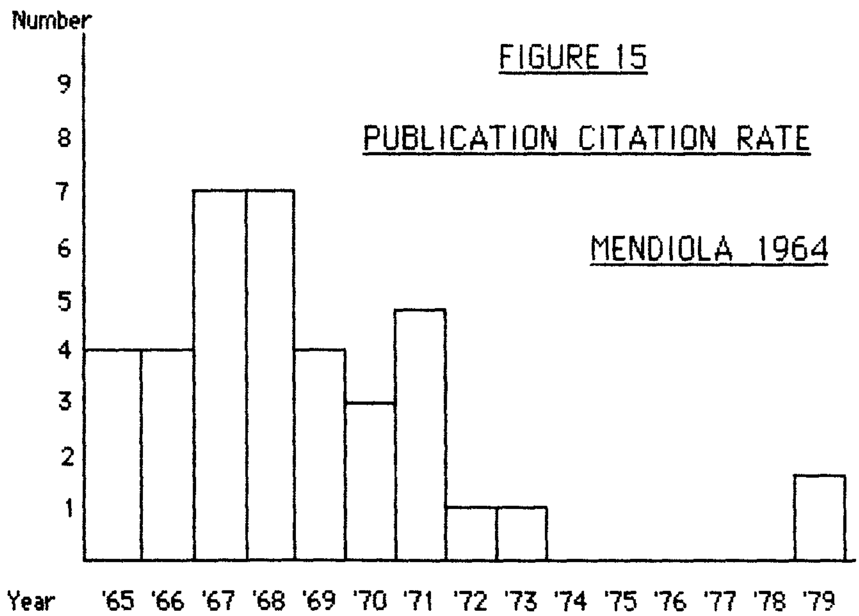


FIGURE 15

PUBLICATION CITATION RATE

MENDIOLA 1964

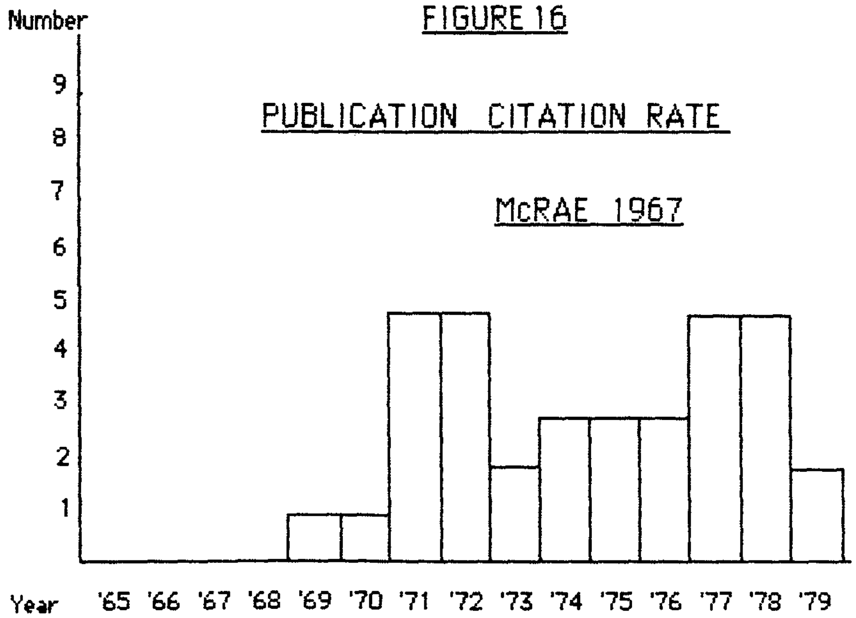
Here, the citation rate for this early paper rose quickly, and then slowly fell away.

The fact that it was cited well in the final year of the period under study showed that the paper had not been "obliterated", but there were several years when it received no citations at all.

FIGURE 16

PUBLICATION CITATION RATE

McRAE 1967



In this case, the paper was not cited at first. There were, in fact, two years until the first citings occurred.

However, following this delayed reaction, the paper was heavily cited for two years, after which the rate declined, and then this was followed by two successive years with a high number of cites in each.

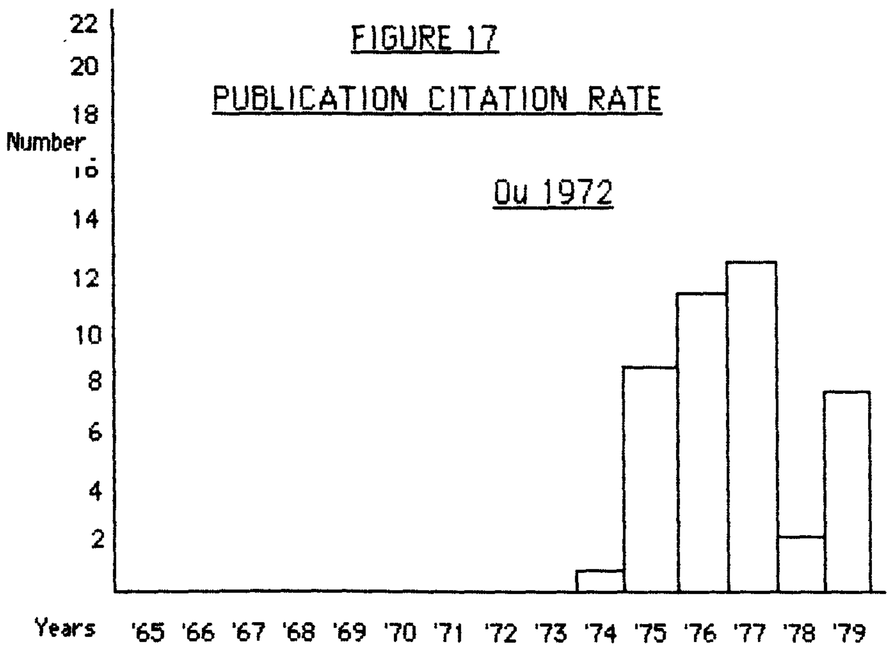


FIGURE 17

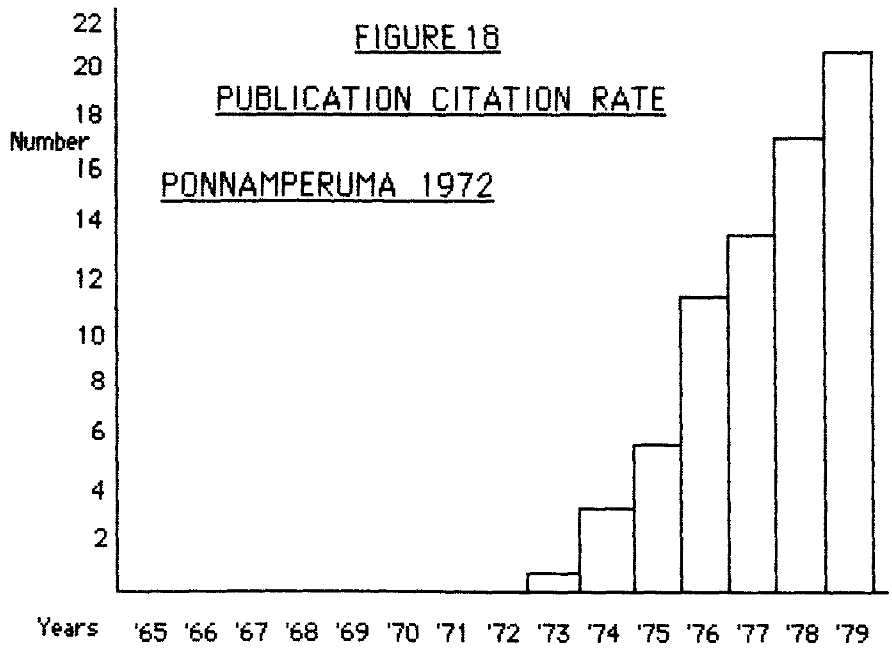
PUBLICATION CITATION RATE

Ou 1972

This is a case where a book on Rice Diseases took time to achieve visibility after publication and distribution.

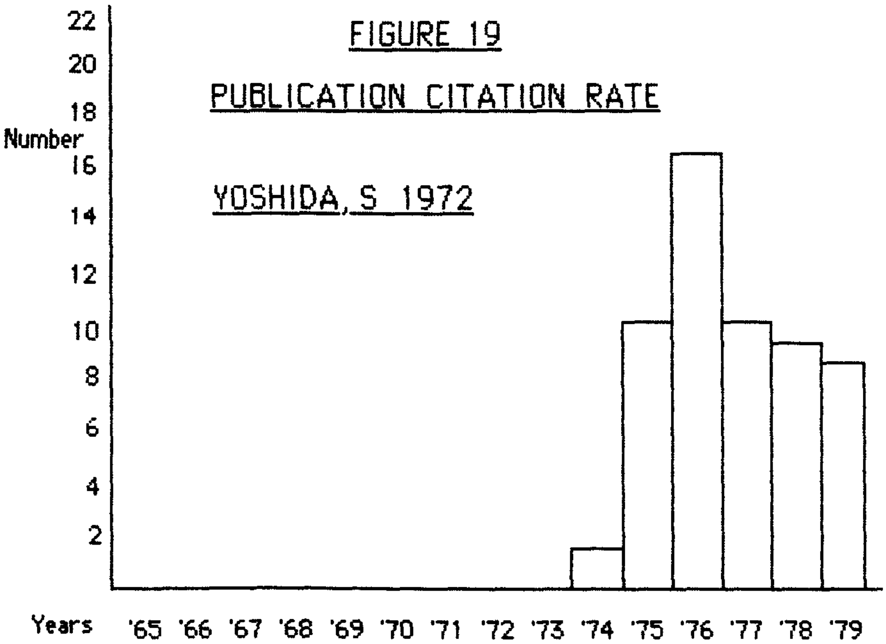
When it did so, it was accorded a very high number of citations in each year.

A slight drop in the rate occurred towards the end of the study period.



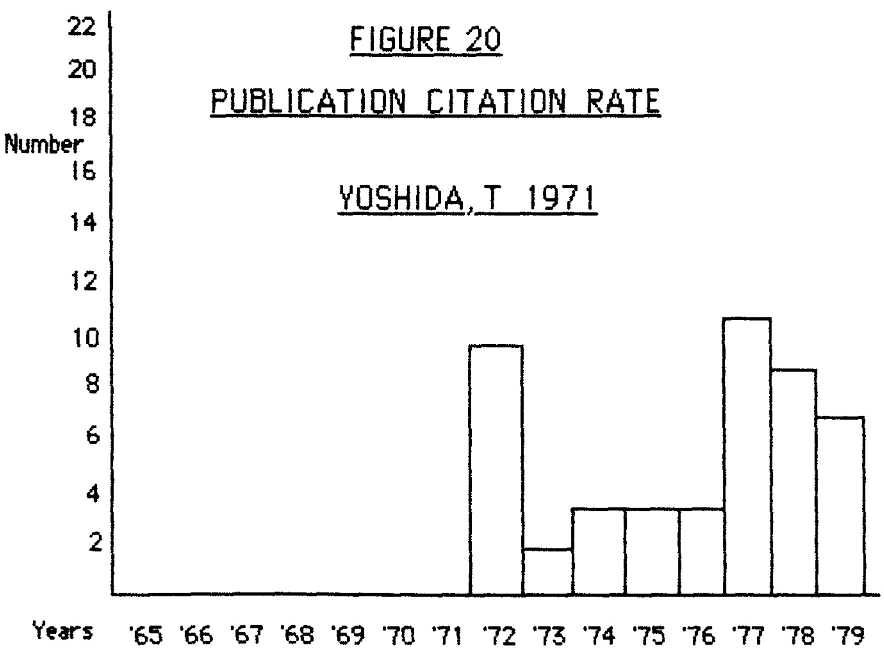
From the start, this major scientific review paper by Ponnamperuma achieved an increasing rate of citation year by year.

This paper gained the largest number of citations of any of the publications studied during the period under investigation.



This review paper quickly gained a high, annual citation rate.

This peaked some four years from publication, from which point the rate slowed.



Citations to the Yoshida, T. 1971 paper rose very rapidly.

A fall away then occurred with the peak taking place some six years after publication.

The twin peak pattern was similar to that of Juliano 1969.

Extension of Study for Four Particular Publications

In the next stage of the investigation, an extended study was made of four publications selected from the existing sample.

These publications, together with the reasons for selection, were:

* Ponnamperuma 1972, since this paper proved to be the major cited work;
* Akazawa 1964, an early paper in another discipline, in this case, biochemistry;
* Juliano 1969, published in the mid part of the first citation study period; and
* Ou 1972, a publication from the final part of the first citation study period.

The citations accorded these publications until the end of 1984, i.e. five years beyond the initial study period, were then assessed. Again, the Science Citation Index was employed for these calculations.

Citations to the Akazawa 1964, and Juliano 1969 papers fell away rapidly, and at the end of the period, one of these publications was not cited at all. The citation span period for Akazawa 1964 would appear to be 18 years.

Citations to the second publication would also appear to coming to an end, after some 15 years. On the other hand, the rate of citations to Ou 1972, would appear to have changed little in the five year period.

In the case of Ponnamperuma 1972, the citation rate remained steady. The results of this analysis are contained in the following Table.

TABLE 10

CITATION FREQUENCY FOR FOUR PUBLICATIONS

Publication	Years				
	1980	1981	1982	1983	1984
Akazawa 1964	1	1	1		
Juliano 1969	4	3	6		2
Ou 1972	15	7	9	11	12
Ponnamperuma 1972	29	34	24	33	29

The cumulative number of citations to the four specific publications, from their appearance until the end of 1984, are shown in the following Table.

TABLE 11

CUMULATIVE NUMBER OF CITATIONS TO FOUR PUBLICATIONS

Publication	Number
Akazawa 1964	51
Juliano 1969	61
Ou 1972	120
Ponnamperuma 1972	225

For each of the four publications, the citation data was analysed further, and the growth in the cumulative number of citations for each was graphed. The graphs are shown in the pages which follow. The absence of a clear S-shaped growth pattern probably indicates that these very highly cited publications, by and large, continued to remain acknowledged among rice scientists despite the many years since their first appearance. Subsequent research in the years intervening between their appearance and the present had not yet eliminated the utility of the information contained in these particular publications.

FIGURE 21

CUMULATIVE NUMBER OF CITATIONS - AKAZAWA 1964

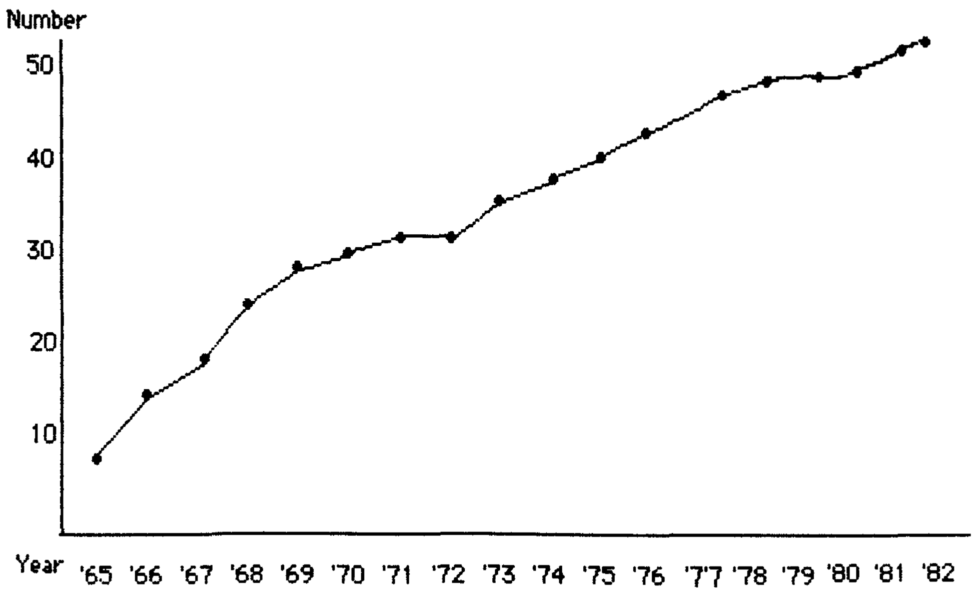


FIGURE 22

CUMULATIVE NUMBER OF CITATIONS - JULIANO 1969

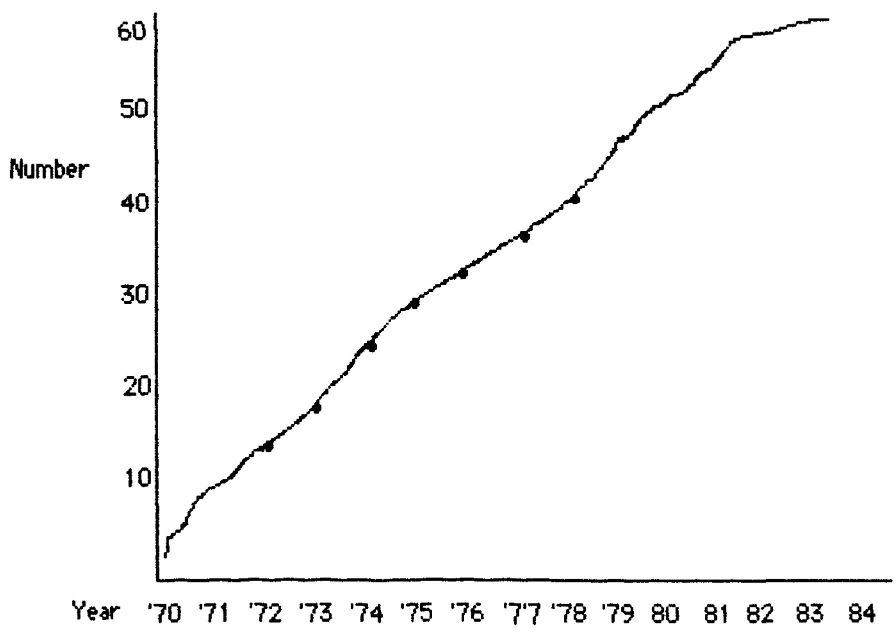


FIGURE 23

CUMULATIVE NUMBER OF CITATIONS - OU 1972

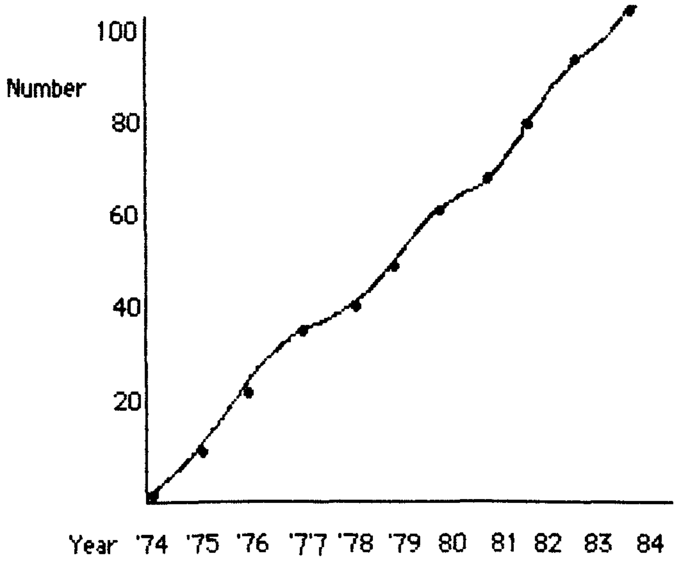
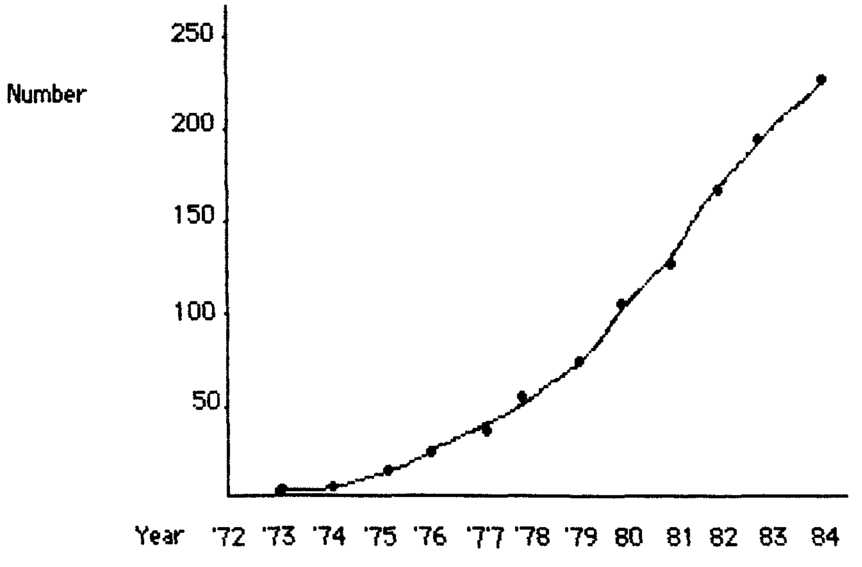


FIGURE 24

CUMULATIVE NUMBER OF CITATIONS - PONNAMPERUMA 1972



Diffusion of Rice Science Information

The graphs in the previous pages broadly portray the diffusion of scientific knowledge, albeit at a second order level, involving the growth in the cumulative number of citations to each particular publication.

The spread of scientific knowledge in the rice sciences would, clearly, be even more accurately illustrated if the intellectual relationship denoted by the citation linkage could be accurately clarified.

This was attempted for two publications, Ou 1972 and Ponnamperuma 1972.

For the ten year period ended 1984, the publications which cited these works were randomly sampled on a roughly one in four basis, and all relevant data about authorship and publication date was collected.

In addition, it had been thought that, by careful reading of each citing publication, an accurate assessment of the specific information expected to be pinpointed in the original works could be made.

However, in general, the citing indicators did not allow this to be accurately determined.

TABLE 12

CITING YEAR AND CITING LOCATION TO OU 1972

Year	Location of Citer *
1975	University of Bonn, West Germany. All India Coordinated Rice Improvement Project, Hyderabad, India. Agricultural Research Service, Seed Quality Lab., Beltsville, MD, USA. Department of Plant Pathology, University of California, Davis, CA, USA.
1976	Punjab Agricultural University, Ludhuna, India. Faculty of Agriculture, Amamalai University, India. Department of Plant Pathology, University of California, Davis, CA, USA. Lilly Research Labs., Greenfield, IN, USA.
1977	Department of Plant Pathology, Cornell University, Ithaca, NY, USA. IRRI, Los Banos, Philippines. Department of Plant Pathology, University of California, Davis, CA, USA. School of Agriculture, University of Melbourne, Vic., Australia.
1978	Central Research Institute, Bogor, Indonesia. Assam Agricultural University, Jorhat, Assam, India.
1979	IRRI, Los Banos, Philippines. All India Coordinated Rice Improvement Project, Hyderabad, India.
1980	University of Wisconsin, Madison, WI, USA. Department of Botany and Plant Physiology, Purdue University, Lafayette,IN,USA.
1983	Agricultural Research Service, Texas A.&M. University, Beaumont, TX, USA. CIAT, Cali, Colombia. Department of Plant Pathology, Central Rice Research Institute, Cuttack, India. Department of Agricultural Biology, Faculty of Agriculture and Forestry, University of Ibadan, Nigeria.
1984	Rothamsted Experiment Station, Harpenden, Herts., UK.

* Several citing locations had multiple entries.

The Tables on the accompanying pages show the results of this investigation.

Table 12 shows the citing year and the location of the research laboratory of the author of each of the publications which cited Rice Diseases, written by Ou in 1972.

The authors were located in both developed and developing countries.

In the case of Ponnamperuma's review paper on "The Chemistry of Submerged Soils", which was also written in 1972, the results are shown in Tables 13 and 14.

Table 13 shows citing year and citing location for publications which cited it and which appeared in the period 1975 to 1980.

Citing year and citing location of authors who published in the period 1981 to 1984 ar shown in Table 14.

Clearly, extensive geographical diffusion of the information contained in the original paper has taken place over these two periods of time.

TABLE 13

CITING YEAR AND CITING LOCATION TO PONNAMPERUMA 1972 FOR PERIOD 1975 TO 1980

Year	Location of Citer *
1975	Department of Soil Microbiology, Central Rice Research Institute, Cuttack, India.
1976	Soil Science Department, North Carolina State University, Raleigh, NC, USA
	Nuclear Institute for Agriculture and Biology, Lyallpur, Pakistan.
	IRRI, Los Banos, Philippines.
1977	Lab. of Soil Microbiology, Central Rice Research Institute, Cuttack, India
	Department of Soils, Punjab Agricultural University, Ludhara, India
	Nuclear Institute for Agriculture and Biology, Lyallpur, Pakistan.
	Flooded Soils Lab., Louisiana State University, Baton Rouge, LA, USA.
1978	Soils Division, CSIRO, Canberra, Australia.
	Letcombe Lab, Wantage, Oxon, UK.
	Department of Soils, Punjab Agricultural University, Ludhara, India.
	Department of Plant Biology, University of Hull, Hull, UK.
1979	Department of Soils, Punjab Agricultural University, Ludhaha, India.
	Lab. of Soil Microbiology, Central Rice Research Institute, Cuttack, India.
	Dept. of Land, Air and Water Resources, University of California, Davis, CA, USA.
	Department of Agronomy, University of Kentucky, Lexington, KY, USA.
	Dept. of Agronomy and Range Science, University of California, Davis, CA, USA.
	Department of Civil Engineering, Tufts University, Medford, MA, USA.
	Department of Primary Industries, Indooropilly, Queensland, Australia.
1980	University of Hohenheim, West Germany.
	Soil and Water Department, University of Alexandria, Alexandria, Egypt.
	Saskatewchan Institute of Pedology, University of Saskatewan, Saskatoon, Canada.
	Soils Division, CSIRO, Canberra, Australia.
	Biology and Agricultural Division, Bhabha Atomic Research Centre, Bombay, India.
	Letcombe Lab. Wantage, Oxon, UK.
	Extraterrestrial Research Division, Ames Research Center, Moffett Field, CA, USA.
	IRRI, Los Banos, Philippines.

* Several citing locations had multiple entries.

TABLE 14

CITING YEAR AND CITING LOCATION TO PONNAMPERUMA 1972 FOR PERIOD 1981 TO 1984

Year	Location of Citer *
1981	Plant Disease Division, DSIR, Auckland, New Zealand.
	Botany Department, University of Melbourne, Melbourne, Vic., Australia.
	Agricultural Chemistry Section, University of Glasgow, Glasgow, UK.
	Soil Science Department, North Carolina State University, Raleigh, NC, USA.
	Applied Biochemical Division, DSIR, Palmerston North, New Zealand.
1982	Dept. of Genetics and Plant Breeding, Marthwada Agricultural Univ., Parbhani, India
	The Phytotron, University of Oslo, Oslo, Norway.
	Department of Agronomy, Iowa State University, Ames, IA, USA.
	Wye Colege, University of Canterbury, Ashford, Kent, UK.
	University of Illinois, Urbana, IL, USA.
	Department of Botany, University of Manitoba, Manitoba, Canada.
	Central Soil Salinity Research Institute, Karral, India.
1983	Department of Biology, Queens University, Ontario, Canada.
	Department of Soil Biology, University of Hull, Hull, UK.
	Waterways Experiment Station, Vicksberg, M., USA.
	Department of Plant Science, University of Cardiff, Cardiff, UK.
	ICRISAT, India.
	Department of Forest Resources, University of New Hampshire, NH,USA.
	School of Agriculture, University of Melbourne, Melbourne, Vic. Australia.
	Botany Department, University of Washington, Seattle, WA, USA.
	IRRI, Los Banos, Philippines.
1984	Institute of Soil Science, Chinese Academy of Science, Nanying, China.
	Botany Department, Kendrapara College, Kendrapara, India.
	Botany Department, Birbeck College, University of London, London, UK.

* Several citing locations had multiple entries.

The Most Cited Work

The Ponnamperuma 1972 paper was clearly, one of unusual significance. This work was a major review of "The Chemistry of Submerged Soils", some 67 pages long, published in Advances in Agronomy in 1972. Some 11 years later, it was given the status of a "Citation Classic", a highly cited publication as identified by the Science Citation Index, at which time, it had received 170 citations. (1) The author, F.N. Ponnamperuma, recounted that, although the outline of the paper was conceived quickly, the task of writing the paper was not easy, since it involved identifying and reviewing papers on the electrochemistry, chemistry, and biochemistry of submerged soils, lake muds and ocean sediments. The papers, some 200 in all, covered subjects from sewage to thermodynamics, and a time span from 1913 to 1971. The review was the most comprehensive and integrated coverage of the chemistry of submerged soils prepared up to that time.

In the words of the author:

> "Flooding a dry soil cuts off its oxygen supply. Aerobic microorganisms use up the trapped oxygen and become quiescent and die. Then anaerobic microorganisms use oxygen-rich soil components in their respiration and set in motion a series of electrochemical, chemical and biological changes that profoundly affect the quality of the soil as a medium for plant growth, its role in eurotrophication of lakes, and its capacity to act as a sink for pollutants.

1. "This Week's Citation Classic." Current Contents. Number 22. May 30, 1983. p 18.

> The paper described the salient features of submerged soils, explained some of them quantitatively in terms of biochemistry and physical, inorganic, and organic chemistry; and showed the implications of the peculiar properties of submerged soils for soil genesis, limnology, crop production and pollution control." (1)

<u>The Citation Classification Study</u>

The next stage of the analysis was concerned with citation classification.

A system was developed for this investigation, based on the work of Lipetz; Moravscik and Murugesan; Chubin and Motra; and Cole.

Reviews of these earlier investigations in this area were described in Chapter 3.

For the particular study described in this thesis, a quarternary level classification of citations was devised.

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1. Ponnamperuma, F.N. <u>Current Contents</u>. Number 22. May 30, 1983. p 18.

Through studying both the citing and cited works, selected information contained in the original publication was assessed as being related to the citing work in one of the following ways:

* Used, supported, applied;
* Refuted, or negated;
* Perfunctory, or noted;
* Not classified.

The investigation was made within the Library of Macquarie University, and involved a detailed consideration of each available publication citing one of the original publications.

Citing publications were identified through the Science Citation Index.

The technique resulted in the accumulation of an immense amount of data which has been crystallized for presentation in the following Table.

Numbers in individual categories were calculated as percentages of the total number of citations given to each publication. The "Not Classified" category comprised citings to non-English journals; errors in the Science Citation Index entries; unavailability of citing journals, etc.

TABLE 15

CLASSIFICATION OF CITATIONS TO ORIGINAL PUBLICATIONS

Publication	Used	Refuted	Perfunctory	Not Classified
Akazawa 1964	10.4	10.4	52.1	27.1
Baun 1970	10		80	10
Juliano 1969	8.7		67.4	23.9
Mendiola 1964			86.1	13.9
McRae 1967			71.4	18.6
Ou 1972			74	26
Ponnamperuma 1972	3.9	2.6	48.8	44.7
Yoshida, S 1972			58	32
Yoshida, T 1971			62	38

It will be noted that, in this analysis, the majority of citations were classified as perfunctory. Some 64 per cent. of all citations were placed in this category.

The prevalence of so many citations in this class was evidence to support the theory of citing proposed by Gilbert. As noted earlier, Gilbert suggested that the main reason why scientists cited earlier work in formal communications was the need to completely convince their fellow scientists, who read the publications, of the validity of the argument and the conclusions drawn from their own particular experiments.

The perspective, offered by Gilbert, viewed persuasion of other scientists as a principal motivation for publishing science.

From the analysis of the data gathered in this investigation, it would appear that rice scientists in the various disciplines were "using" information, published in earlier work by Institute scientists, in the words of Gilbert, as "tools of persuasion." It should be noted that the later publications would have conveyed scientific information which most probably had, itself, already been passed to scientists via informal communication channels.

Publication in science only comes at the end of a very long path. Typically, conferences workshops, and discourses among scientists would have all taken place before publication.

Summary of Chapter

The principal aim of the investigation was to achieve an understanding of the formal scientific communication network formed through publications which had been originated by IRRI scientists, and to clarify the nature of the subsequent utilization of rice science knowledge.

Scientific publication productivity for the period 1964-79 was gauged, together with an assessment of the number of the citations which were accorded the publications from this period.

Some 18 publications received 30 or more citations each, and half of this sample was selected for detailed analysis. All were in the category of basic science. The citation rate for each publication was then determined. Four particular publications were then selected for extended citation analysis through to the end of 1984.

The global diffusion of rice science knowledge was portrayed in terms of dates and geographical location of authors of subsequent publications citing the earlier selected works.

Application of a quarternary level system of citation classification indicated the propensity among subsequent citing authors to use particular information contained in the earlier publications in the persuasion of scientific readers.

Scientific publication occurred late in a sequence of events which followed the completion of experiments and the initial, and largely oral, dissemination of experimental findings.

CHAPTER 6

UNDERSTANDING KNOWLEDGE UTILIZATION IN THE COMMUNICATION

OF

INTERNATIONAL AGRICULTURAL RESEARCH

"In the long run, we must recognize that knowledge itself - theory, invention, discovery, technology - and human skills must be shared globally if the world hunger problem is to be solved."

(Wharton, 1980)

<u>Scientific Information Transmission and Transformation</u>

Scientific communication constitutes a system in which the participants are inter-connected by channels. Information, which is largely a body of loosely connected facts, and/or knowledge, a more inter-related and ordered body of facts, is exchanged among the participants.

Within the system, two processes are continually taking place - transmission and transformation. Transmission refers to the passage of messages, while transformation denotes that the nature of the messages can change due to internal processing by the entities in the system. Each discipline in science can be seen as a part of a total system, subdivided again into a further multitude of component sub-systems, which specialize in the generation, verification, storage and dissemination of information and knowledge in particular substantive areas. The institutional bases for these activities occurs within such bodies as scientific research organizations, scientific libraries and scientific societies.

The knowledge macrosystem in science does not possess a linkage person, as occurs, typically, within the agricultural knowledge generation and use system, known as Agricultural Extension. Instead, knowledge generated by the research scientist is placed, initially, in appropriate informal channels; the public portion of the scientific communication system appears later. Throughout the sequence, the individual scientists engaged in the information-exchange mode are marked by alertness and active seeking of knowledge relevant to their current or future research. Scientists monitor the performance of this mechanism, since it is so crucial to their work, and if it is shown wanting, modifications are devised to affect improvements. Scientists, working in a discipline, or sub-discipline, can be nominated as knowledge users or as a knowledge resource. Some oscillate between each role, though the existence of a scientific elite recognizes that a small, core group within each discipline constitute the latter category.

Scientific Communication Networks

Communication networks are a distinguishing feature of science. Since communication, the process in which participants share information with one another in order to reach mutual understanding, is the life-blood of science, and myriads of networks occur in science, in which patterned flows of information move between inter-connected individuals, the convergence model of communication is an appropriate descriptor.

Communication convergence is, by definition, "the tendency for two or more individuals to move toward one point or for one individual to move towards another, or for two individuals to come together and unite in a common interest or focus." (1)

The definition of knowledge utilization has long proved difficult for researchers.

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1. Rogers, E.M. and D.L. Kincaid. Communication Networks. Towards a New Paradigm for Research. Op. Cit. p 346.

A common approach has been to distinguish between conceptual and instrumental uses of knowledge, where conceptual use refers to changes in the way users think about problems, while instrumental use denotes changes in behavior, especially changes that are relevant to decision-making. (1) Other taxonomic classifications of utilization also exist, but raise awkward problems in interpretation.

In the investigation described in this thesis, the utilization of knowledge in rice science was examined specifically in terms of its instrumental use, as denoted by scientist-authors who gave citations to earlier published work.

Scientist to scientist communication in the global international agricultural research centre network was one of several major tasks in communication discussed at the conference on the Communication Responsibilities of the International Agricultural Research Centers, held at the International Rice Research Institute in 1979.

The meeting recognized that the scientific information networks to which agricultural research scientists belonged were of critical importance in the utilization of research findings emanating from the international agricultural research institutes. It pointed out that the networks were fluid and overlapping, and that information was the bond that held the networks together.

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1. Weiss, C. ed. Using Social Research in Public Policy Making. Lexington, MA: Lexington Books. 1977.

The Report noted:

> "...scientific communication serves important purposes beyond conveying information. Publication in a prestige journal provides a scientific reward and recognition system. It is also an accepted method of academic claimstaking, or of establishing intellectual property. The need and desire for scientists to publish is strong, valuable and cannot be ignored." (1)

Science itself grows and develops through the accumulation of information about discoveries that modify or validate previous knowledge about topics in the various scientific disciplines.

An obligation for scientists is that they contribute to the stores of knowledge in their respective specialities.

A Lengthy Communication Sequence

But the processes involved in generating scientific information, and making it available to the information pool for acceptance by fellow scientists, is, for the individual scientist, a lengthy path, which if it is to be followed, involves a sequence of steps.

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1. ADC-IRRI. Summary of the Recommendations of the Conference on the Communication Responsibilities of the International Agricultural Research Centers. Los Banos: IRRI 1980. p7.

Once the scientist believes he can report the results of a research investigation, he ordinarily begins to disseminate the findings through workshops and conferences.

Since its earliest days, the Institute has been renowned for the importance it has placed on such meetings, and the recognized success of such events. Typically, all manner of informal communication channels were employed in disseminating research results further. Thus, discussions begun at conferences and workshops were followed by subsequent correspondence between Institute scientists and others. Often the conferences and workshops were followed by subsequent correspondence between Institute scientists and others on return to their home research stations in other parts of the world.

Then, in typical fashon, scientists launch the information which is the outcome of research into even wider territory. This may involve presentation of papers at meetings elsewhere in the world, even perhaps to scientists who are part of neighboring disciplines.

This permits the individual rice scientist to hone his results, order the logic of his arguments and clarify each conclusion from his research endeavors.

Each of these steps takes time but for the productive scientist, each is mandatory. These information exchanges among scientists remain crucial to the process of science.

Publication in Science

The move to publish the results of a scientific experiment marks a new phase in overall sequence. Scientific publication, for start, ordinarily occurs only after a fair time lapse from the conclusion of the experiment. But, as well, once a scientist submits his work in a form suitable for publication, the results of the experiment and the conclusions drawn from it remain closed off from further public scrutiny while undergoing editorial and referee evaluation. It is important to acknowledge Ziman's perspectives on scientific publication. Thus, scientific publication has three characteristics: it is fragmentary, derivative and edited.

> "It is no longer necessary to amass a vast quantity of material, or to conceive a complete new 'world system', fully armed at all points, before going into print... Although the best and most famous scientific discoveries seem to open whole new windows of the mind, a typical scientific paper has never pretended to be more than another little piece in a large jigsaw - not significant in itself but as an element in a grander scheme". (1)

The tradition of science in seeking - and the offering of individual scientists - many modest contributions to scientific knowledge has been the secret of science since its beginnings.

Such a procedure achieves a professional strength far outweighing anything that an individual scientist could exert.

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1. Ziman, J. "New Knowledge for Old." Nature. 227: 1970. pp 890-894.

Also in Ziman's view:

> "Scientific papers are derivative...because they lean heavily on previous research...(A) list of citations must always be published with every new contribution. These citations not only vouch for the authority and relevance of the statements they are called on to support; they embed the whole work in a context of previous achievements and current aspirations...Indeed, one relies on the citations to show its place in the whole scientific structure..."(1)

An extraordinary degree of cooperation is a hallmark of science, and the corporate product of the worldwide community of scientists is the store of scientific knowledge.

Scientific Publication Structure

As for the the construction of scientific papers themselves, Ziman pointed out that these are substantially edited versions of the events surrounding the research endeavor.

Such editing is done, by the scientist concerned, by himself, on his own written work, well ahead of the editing undertaken by the person responsible for the journal to which the paper is submitted.

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1. Ziman, J. "Information, Knowledge, Communication." Nature. 224:1969. pp 318-324

> "A scientific paper...is a cunningly contrived piece of rhetoric. It has only one purpose; it must persuade the the reader of the veracity of the observer, his disinterestedness, his logical infallibity and the complete necessity of his conclusions...Scientists use jargon to to show their work within a reputable context... They favour the passive voice, the impersonal gender, and the latinized circumlocution...(as)... a device of 'inverted rhetoric' by which an apparently modest and disinterested tone enhances the acceptability of one's utterances." (1)

Revision and editing by the scientist writing the paper prior to submitting it for publication removes any comments that could be made about such matters as false starts, unncessary research complications, and major difficulties that were encountered during the research process.

The scientific paper thus, in typical fashion, describes, with the vision of hindsight, an ordered sequence of events. These will involve the delineation of the research topic, a search of the literature, the selection of the research methodology to be use, the execution of the investigation, the outline of the results, and the discussion of the results.

Getting the paper into print may take considerable time. The editor of the publication to which the paper is sent will, after giving it a general overview, send it to external referees - usually respected senior scientists in the particular discipline or sub-discipline - for a "blind review" of the paper.

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1. Ziman, J. Ibid. p 318.

Any comments they make may be sent back, anonymously, to the author by the journal editor, from which point the author can then prepare a revised version of the paper for resubmission.

If acceptable to the editor, the final paper may be included in a future issue of the journal.

The printing of the journal containing the article in question, and its distribution to members of the scientific community who may wish to read it, add additional time to the whole process.

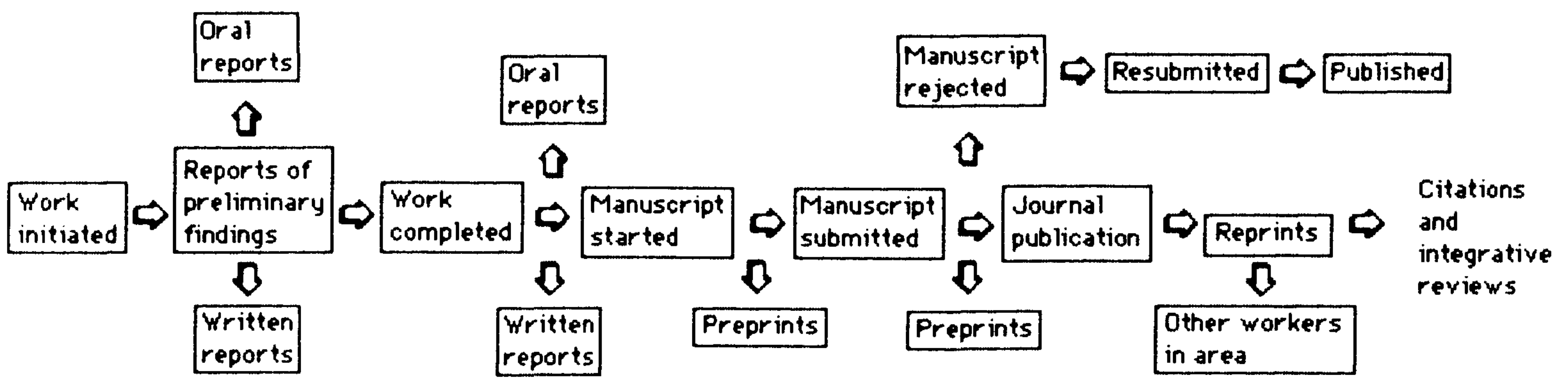
The "after-the -event" view of the scientific experiment, which is received for consideration by fellow scientists, is a distinctly unusual presentation of information, in many respects, and only does so, since the reordering of events and the sifting process involved presents findings in an article which meets the canons of established scientific tradition and practice.

The movement of the information obtained in an experiment into a final, published form, represents, in reality, a process of assimilation.

The steps in the process are illustrated in the Figure on the following page.

FIGURE 25

THE SCIENTIFIC COMMUNICATION SYSTEM



The Persuasion of Fellow Scientists

The author's primary objective in drawing up the final scientific publication is, ostensibly, to persuade and convince the reader that the experimental findings and conclusions from the whole work, should be accepted as valid knowledge.

The form and style of the argumentation is determined by procedures accepted by members of the scientific profession, and the paper for publication will be assembled, with an appropriate list of references attached to it, with that aim in view.

The embedding of the paper within a citation framework is an important part of this assimilation process.

Science progresses, typically, through the assimilation of accumulated knowledge, emanating from new experimental discoveries, and these modify or validate previously held perspectives in a specific part of a discipline.

Publication in Science and Technology

The investigation has shown that networks have formed among rice scientists contributing to certain basic disciplines in agricultural science. Every formal communication in this exchange network marks a crucial stage in the assimilation of

scientific knowledge. Publications which convey this scientific knowledge represent part of a linkage mechanism among members of the scientific community.
However, it should be noted that the content of this communication system favors basic research.

The reason for this emphasis may well reflect Price's contention that:

> "I suggest that science may be papyrocentric, but that a large part of technology is papyrobphobic." (1)

The spread of information about applied research and technology, both of which are likely to be founded on basic research, tends to involve informal, rather than formal communication mechanisms.

The utilization of agricultural science knowledge necessarily involves, at the primary level, the establishment of suitable linkage arrangements between basic and applied researchers and appropriate technology production systems.

Transmission and transformation of scientific information takes place in an interactive way within these systems. Both informal and formal modes are important, with the latter being pre-eminent in the communication of the more basic scientific information and knowledge.

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1. Price, D. deS. "Citation Measures of Hard Science, Soft Science, Technology and Nonscience." in C.E. Nelson and D.K. Nelson, eds. Communication Among Scientists and Engineers. Lexington, MA.: Heath Lexington. 1970.

Scientific Communication Activities Summarized

It is clear that scientists spend a considerable proportion of their working time in communication activities, involving oral and written, informal or formal means. Diverse modes are present, which depend, as noted, on the circumstances, and include face-to-face contact, telephoning, and a variety of written materials, such as scientific papers, letters, books and reports.

The communications can be direct and specific to particular persons, for example, by letter and telephone. Oral communication is, largely, direct, through lectures, personal conversations, or delivering a paper at a conference or workshop.

Much of the scientific literature, where scientific publications are concerned, constitutes an indirect channel, where potential users of the scientific knowledge contained in such publications have to identify, locate, and assess the information they contain, before they can utilize that information, if at all.

These scientists, thus, pass through several stages, which begin with the critical identification of documents likely to carry information of relevance to their own research.

The existence of possibly needed literature may come about from such diverse ways, as a mention at a conference, a colleague's reference, or purposeful scanning of the scientific literature.

The nature of scientific information, which follows the accepted rules and conventions, varies greatly. In the strictly informal mode, the scientific information may well be preliminary, and not confirmed as reliable scientific knowledge. Typically, it will be in abstracted form and possibly incomplete. Usually, such information is conveyed orally to a small workshop or conference attended by scientists in the relevant discipline. The setting provides the opportunity for some assessment of the research.

As additional presentations follow, further refinement occurs, and the scientist begins the task of preparing a manuscript. In this way, the experimental reporting becomes increasingly formalized over time. This evolution takes place in an almost predictable way.

Scientific communication, as noted, is a highly interactive operation. All stages - the initial phase of research when a literature search is done, or at the preliminary presentation of results at a small meeting, or at the final publication time - involve interaction and exchange of scientific information.

All conclusions from scientific research are not necessarily of significance; nor, for that matter, can it be said that all significant scientific contributions are always immediately recognized and accepted by the relevant scientific community. Only, with the passage of time, and following dialogue with fellow scientists, will these issues be resolved.

Throughout this time, the individual scientist constantly processes the information he has available. For the "package" as a whole, he sifts and excludes irrelevant information, strengthens the logical presentation, and integrates existing, acknowledged information with his own contribution. The aim is to construct an outcome which can be conveyed meaningfully to peers. Constant feedback sought from fellow scientists underscores the basis of this activities.

The process takes considerable time. From the start of research to the incorporation of research results into the body of knowledge, as for example, in textbooks, has been shown to amount to more than a decade in some areas of science.

The tangible outcome of science in terms of publications has tended to highlight the formal communication sector. As well, the labor and cost in producing such products shifts attention away from the informal area. Information disseminated in the informal sector lacks the stability of that in the formal domain and possesses an ephemeral aura. Redundancy in the informal sector is accepted as commonplace. This stage, however, is crucially important in refining and shaping the final manuscript presentation.

Since the citing of an earlier paper in the manuscript typically denotes, in general terms, use of certain information contained in that paper by the author of the current publication, the argumentative process would have been enhanced, and probably speeded, had the author been required to notate the specific reason for each particular citing. After all, the author has full knowledge of this situation.

Swanson has made the point cogently:

> "The importance of the <u>Science Citation Index</u> lies in the fact that it captures the link that an author of a journal articles establishes when he cites, that is, makes reference to some other article. By so doing the author indicates that he has constructed some kind of relevance bridge (at least occasionally in the sense of frame of reference) between his own and the cited article.
>
> Thus he has left a trail that in part describes the end result of his own trial and error adventures in using the scientific literature.
>
> Such trails are central to the process of scientific communication and so would seem to be a good point of departure for developing better information services.
>
> However, what is lacking in present systems is any convenient and rapid method for discovering the nature of the relevance link whic the citing author has established. This can be discerned only by studying the citing article.
>
> We might imagine a future citation-based system which provides rapid access to just those portions of the citing article which reveal the nature of its relationship to the cited article. Here would be one "suggestive fragments" mentioned earlier.
>
> If the cooperation of authors could be enlisted (or coerced) in the process, citation practices might be considerably improved by making more explicit the reasons for citing and by utilizing more stringent criteria as the basis for citing." (1)

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1. Swanson, D.R. "Information Retrieval as a Trial-and-Error Process." <u>Library Quarterly</u>. 47: 2: 1977. pp 128-148.

However, adding a new citation practice of this type to the established procedures of scientific communication would not have occurred in the past no matter how desirable such a move would appear to be.

For a start, the basic conservative nature of the scientific profession would militate against its introduction. A major reason for the absence of this desirable practice could well derive from the likely small number of active scientists working at any one time in a particular field.

Within such sub- disciplines, a small network of scientists is likely, as already described, to be continually interacting with each other especially in informal settings. As time passes, new, and perhaps smaller, sub-sections are likely to hive off and become separate networks.

Thus, and especially in close knit groups, members of these scientific communities are likely to deduce the nature of the links with earlier work as a consequence of such extensive interaction with each other.

There would be good reasons to acknowledge that many scientists in these circumstances would be likely to understand the citation linkage character, without specific details being included in the publication.

However, as the number of scientists engaged in international agricultural research increases in the years ahead, the desirability of this procedure may be worth further consideration.

The size of sub-fields, and the geographical spread of scientists, could change to the point where the criteria for effective interaction, and the consequent deep understanding that scientists have in particular areas of knowledge, would remain unmet.

In such circumstances, the introduction of an efficient, rapid, descriptor system to identify the nature of the citation linkage in formal scientific communications in rapidly expanding disciplines, would be valuable.

Conclusion

The investigation recorded in this thesis has been concerned with aspects of formal scientific communications emanating from the International Rice Research Institute, the international agricultural research centre located in the Philippines.

The study identified, through analysis of citations in publications, significant rice research investigations, and showed that scientists subsequently working in various disciplines, and in a wide range of locations, used information contained in the earlier publications in support of their own investigations.

The production process for formal communications in the rice sciences tends to emulate traditional behavior in other branches of science.

Formal publications emerge after a long period of time and represent an important step in the assimilation of scientific knowledge.

The movement of experimental results into a published form by scientists is perceived more in terms of staking property claims in archival literature, rather than a purposefully direct exchange of information with immediate colleagues.

The mandatory scientific communication function would have been largely met during an earlier phase in the sequence leading to publication.

Effective communication linkages are necessary at every stage from basic scientific research in agriculture to applied agricultural research and the development of agricultural technology.

In the past 25 years, the Institute has achieved outstanding success in scientific research and technology production.

By the year 2000 - a mere 15 years from now - the population of the world may comprise 8 billion people. Most will be living in the Third World; a majority will see rice as life itself.

The task of growing more food for these people will depend to a great extent on further achievements in international agricultural research.

The scientific communication system, and the means whereby scientific knowledge can be utilized, are essential components in the drive to meet this challenge.

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