# THE RESPONSE OF RICE TO LIGHT

**By Jose R. Velasco, Ph.D.**

## Introduction

Let me start with a digression: Legend has it that Diogenes once went about Athens carrying a lantern in broad daylight looking for an honest man. The reporter went further in saying that Diogenes found none.

Diogenes has been cited as a prototype of a researcher because he searched, then searched again until he exhausted the possibilities. However, let us make a critical analysis of Diogenes' actuation to determine if he measures up to our concept of a researcher: First, we will note that he set his sights too high. He knew that he was not likely to find an honest man because all men were dishonest in various degrees. For example, if he were honest with himself, he would not cover his delicate parts with clothes. (Do you remember the anecdote concerning Sir Winston Churchill? At the height of a recrimination with a lady friend, he was said to have rushed out of the bathroom, and wearing only a weak smile, told her: "Honestly, I am not hiding anything from you.") Secondly, he used an irrelevant tool to attain his objective — i.e., a lantern in broad daylight to locate an honest man. Then his results were likely to be highly subjective because he did not specify his criteria of an honest man. And fourthly, he adopted a rigid frame of classification. Thus, a person can be nothing but honest or dishonest; he can not be non-honest. In this system, a singer for example is not judged by the beauty of his music but rather, by the honesty of his singing. Incidentally, Diogenes was fortunate in having somebody to report his deeds; otherwise, this account would not have come to us. To parody Gray's Elegy,

> he could have been "born to blush unseen
> and waste his queerness in his island lair."

Unhapilly, in this critical analysis, we end up by being critical of Diogenes.

Now let me recount to you how much my colleagues and I are equally guilty of Diogenes' errors of commission and ommission.

## Setting sight in research

As a novice in research during my early days in Los Baños, I had an inordinate ambition to contribute to the science of rice growing. My thought then was to eskew the biochemistry of the plant so that it would produce starch exclusive of cellulose. The job was apparently simple: we induce the plant to make only alpha-glucose linkages and inhibit the formation of beta-glucose, its stereoisomore. In this way, we can double the grain yield without having to correspondingly increase the biomass. The foolish thought led me to the study of hormones and enzymes. However, I have to confess that up to now, I have not yet seen "light at the end of the tunnel." Obviously, I set my sights rather high.

On the other extreme, I have been running experiments on the application of fertilizers to rice. The job did not give much of a challenge, and most of the time I caught myself delegating the work to the laborers. The results were not very exciting: a fertilizer may be better than two or three others when given to a particular variety, planted in a given soil, at a certain time. However, when the trial is repeated, a different (pecking) order among the fertilizers may be obtained. The study could be a never-ending busy work which could not get me anywhere.

I have since concluded that the essence of a self-rewarding research effort is to choose the area and level of study which one can handle with competence. And this will include the ability to circumscribe a problem within testable limits. However, despite this conclusion I still have to shuttle and fumble. Like the pointer in a balance, I swing from left to right oscillating past the rest point.

### The use of relevant procedure

Common sense dictates that we should proceed to attain our objectives via the most relevant and direct way. Hence, we thought it queer that Diogenes would use a lantern in broad daylight in his search for an honest man. However, we may be reminded that there are various degrees of queerness. For example, Columbus was thought queer when he proposed to reach the East by sailing west. Again, when I was in the grade school, I could not comprehend how human voice could be sent around the world without any visible medium of transmission.

In our study on the effect of light, we started with the premise that light is essential in photosynthesis. Our immediate thought was to supplement sunlight with artificial light — that is, to use a lantern in broad daylight — and measure its effect on photosynthesis. This may be in terms of carbon dioxide consumed or amount of sugar (or starch) produced.

A friend suggested to use the idea of planting a crop of rice at different dates in order to expose them to different amounts of sunlight. (The amount of sunlight varies with the seasons.) We initially rejected this idea, because the approach is indirect; furthermore, other factors such as rainfall, humidity and temperature vary with the seasons, as well. These latter factors might eskew the results.

However, reviewing the literature, we found that Peralta (1919) had done just that: He planted a crop in the different months of the year. . . With some mental reservation — we tried to repeat Peralta's experiment with a slight modification. Besides the variety Inintiw which he used, we planted Elon-elon. Inintiw is early-maturing and grows in flooded soil.

This incident illustrates our diffidence. We tend not to entertain a strong feeling against a procedure, which (initially) we think irrelevant.

It is curious that intermittently, we have been debating to ourselves the merits of a direct approach in research. Adverting back to the quest for a route to the Orient, the early Europeans throught — and very correctly — that to reach the East they had to go east. But then, they precluded the chance of discovering a new world.

## Criteria of results

It is a rare occasion when researchers pause to cogitate on the criteria of results which they have been using. This is because most criteria come as a natural consequence of the objectives of the experiment. For example, if we are comparing the performance of different varieties, yield of grains comes naturally to our mind as a criterion of performance.

However, in a less positivistic field, such as the social sciences, concepts and entities are not easily measured; hence difficulties often arise. Such concepts as honesty, love and happiness may defy attempt to concretize them. When Diogenes set out to look for an honest man, he probably did not ask himself what characteristics identify a man as being honest. He perhaps should have asked himself: (1) Should an honest man always tell the truth? What is truth? (2) Should he take only the things which belong to him? For example, are we Filipinos honest in taking the Freedomland? are the Vietnamese? are the Chinese? (3) Is it honest to cover up something which exist, such as a murder? How about covering one's delicate parts?

Even in the more positive sciences of physics and biology, it may be hard to determine what criteria or properties are to be observed and recorded. This usually arises from the fact that several concatenated processes proceed before a measurable entity is produced. Thus, the photosynthetic chain starts (in rice, as in other plant) with the splitting of water to form nascent hydrogen; the latter reduces in a few steps the carbon dioxide which has been "fixed" to a shuttle; then, three-carbon and six-carbon sugars are formed. The latter may be translocated to the grain, polymerized and deposited as starch. Since the intermediates are inconvenient to measure, grain yield is taken as a criterion of performance. But please note that grain is quite remote from the first step in photosynthesis. If perchance the sugar gets polymerized as cellulose and deposited in the stem, our criterion sustains a big margin of error.

During the preparation for the research undertaking, our mentors (i.e. yours and mine) have dinned on us the importance of sticking to our criterion of results. If we "change horses in mid-stream" we will obtain a blurred picture of what happened in the experiment. On the other hand, a single-minded use of criterion can blind us to certain important deviances. For example, in the experiment on planting rice in different months, we set to observe the different grain yields. When Elon-elon planted in February did not produce grains within 180 days, we thought that our culture got spoiled. Hence, we missed to note the effect of photoperiod on rice.

This brings to mind an incident which illustrates how a different criterion can lead to an entirely different conclusion — and conversely. I once showed a friend the beautiful water-soaked specks which we produced on the leaves of coconut seedlings by withholding magnesium from the culture solution. My friend, who happened to be a plant pathologist, did not get attracted to the water-soaked specks; instead, he noticed the few brown blotches in the other leaves. In the tone of a Eureka, he exclaimed: "I bet you, you have a beautiful case of infection by *Ceratosmella paradoxa.*"

### Results and their interpretation

The conceptual frame with which we view the results of our experiment often determines whether or not we would make a discovery. For example, Lord Rutherford and his colleagues adopted a nonstatistical frame of mind in making their far-reaching discovery of the nucleus of the atom. They bombarded a very thin gold leaf with alpha particles and most of the particles went through, implying that the atoms in the leaf were empty. Only one alpha particle out of 6.17 million got deflected by more than 90 degrees. Other scientists observed the same phenomenon earlier than Rutherford but they regarded the straying as fortuitous — i.e., it was not statistically significant. Rutherford, however, interpreted this in terms of an atom which is for the most part inert to alpha particles but has a very small solid core — the nucleus.

In microbiology, a plant pathologist in Los Baños claimed that he used to be exasperated by contaminations in his bacterial cultures. Around a putative fungus colony he used to observe a clear halo where no bacteria would grow. If, instead of throwing away his contaminated cultures, he had interpreted the halo in the same way that Fleming did, he could have been a pioneer in the study of anti-biotics.

In medicine, a wrong diagnosis can lead a doctor to prescribe a cure which is irrelevant to the disease. The worst thing which could happen is that the patient could be killed by the prescription. Because medical doctors hold the life of their patients in their hands, medical schools admit only the best among the student applicants.

The results of our experiment with Inintiw essentially confirmed those of Peralta, and this made us jubilant. Much later, Yoshida and Parao (1967) obtained parallel results, using a different early maturing variety. Since our results were not published, we will not attempt to recall them here; instead, we will simply point out the salient points of these two published papers. Figure 1 shows that Peralta obtained high yields in his plantings of February, March, April, May and June. Likewise, Yoshida and Parao's best crops were planted in March, April, May and June. Peralta's February planting was harvested in June, or it took 134 days to mature; his June planting was harvested in September, taking 141 days to mature. The best grain-to-straw ratio of 0.63 was obtained in the May planting, followed by 0.59 in the June planting. The vegetative period of these two crops occurred in May to August, a period of high possible sunshine hours (figure 2). (However, the actual sunshine hours in this period was rather low and erratic, and its solar radiation was not very high either; (figure 3). In addition, its rainfall was high, especially during July and August (figure 4); however, high rainfall is also noted in other periods, especially September to November. Perhaps, the high yields and favorable grain-straw-straw of these two plantings were favored by a combination of high possible sunshine hours (long days), and high rainfall — with a consequent high relative humidity. The latter condition results in lower evapotranspiration.

On the other hand, Elon-elon, a late-maturing variety, presented a different picture. It flowered so erratically that it simply did not fit in with our hypothesis. For example, on the basis of sunshine hours received, the crop planted in February would be expected to give the highest grain yield because its growth period was longest. In fact it was among the lowest

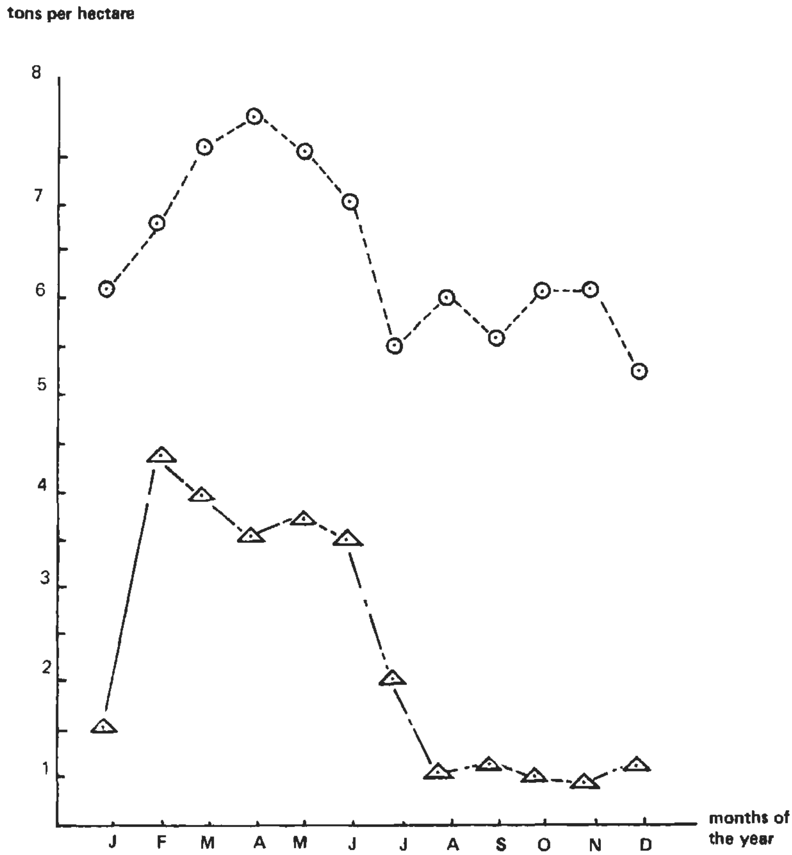


**Fig. 1. Yield of Inintiw (lower curve) and IR 747 B2-6 (upper curve) planted at different months of the year.**

yielders. Figure 5 shows that Elon-elon flowered in 75 days when planted in January and in 281 days when planted in February. This was quite baffling to us at the time.

In our course in plant physiology, we had been told in passing that Garner and Allard (1920) reported that short days could induce flowering in tobacco, soybeans and other crops. However, we missed to relate this with out observation on rice because it is a tropical crop and day-length does not fluctuate very much in the tropics. Hence, in our state of quandary, we left our data idle in our file.

This experience of ours illustrates again the dictum that "discovery starts in the mind." If we had not tacitly limited our frame of mind to the working hypothesis, we would not have had the blinders as it were, which made us miss the implications of the erratic flowering in rice. According to Medawar (1979), to make a

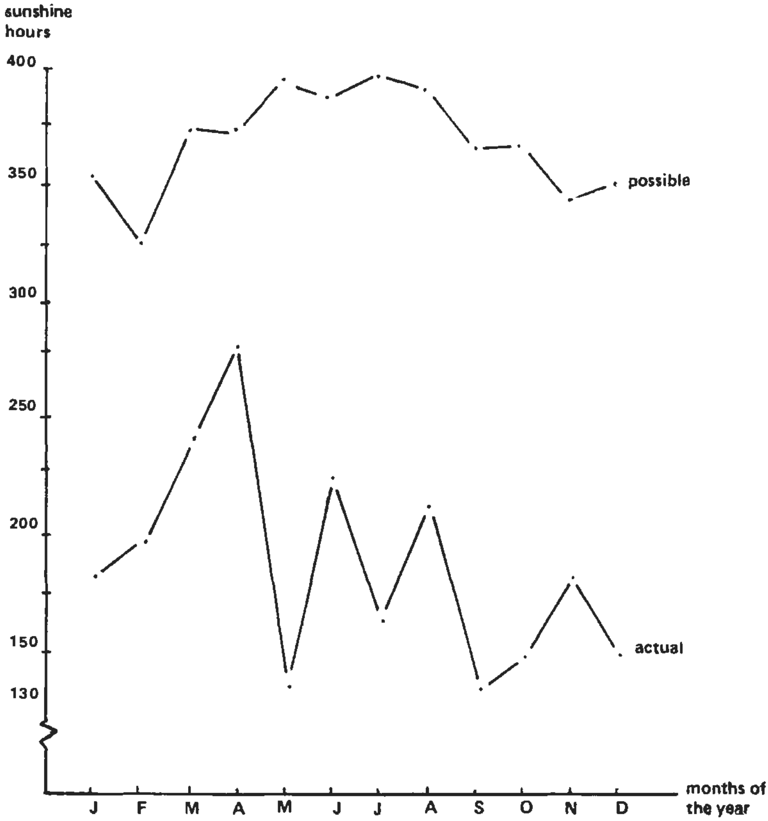


**Fig. 2. Number of sunshine hours per month in Los Baños.**

discovery "the mind must already be on the right wave-length, another way of saying that all such discoveries begin as covert hypothesis — that is, as imaginative preconceptions or expectations about the nature of the world, and never merely by passive assimilation of the evidence of the senses." He went on to say that discoveries may be grouped in two categories: synthetic and analytic. "A synthetic discovery is always a first recognition of an event, phenomenon, process or state of affairs not previously recognized or known." On the other hand, an analytic discovery is "the result of sustained dialogue between conjecture and refutation."

Our state of quandary remained for about a decade; then in 1951 (and after a visit in Borthwick's laboratory), we decided to re-study the effects of daylength on the flowering of rice. This was

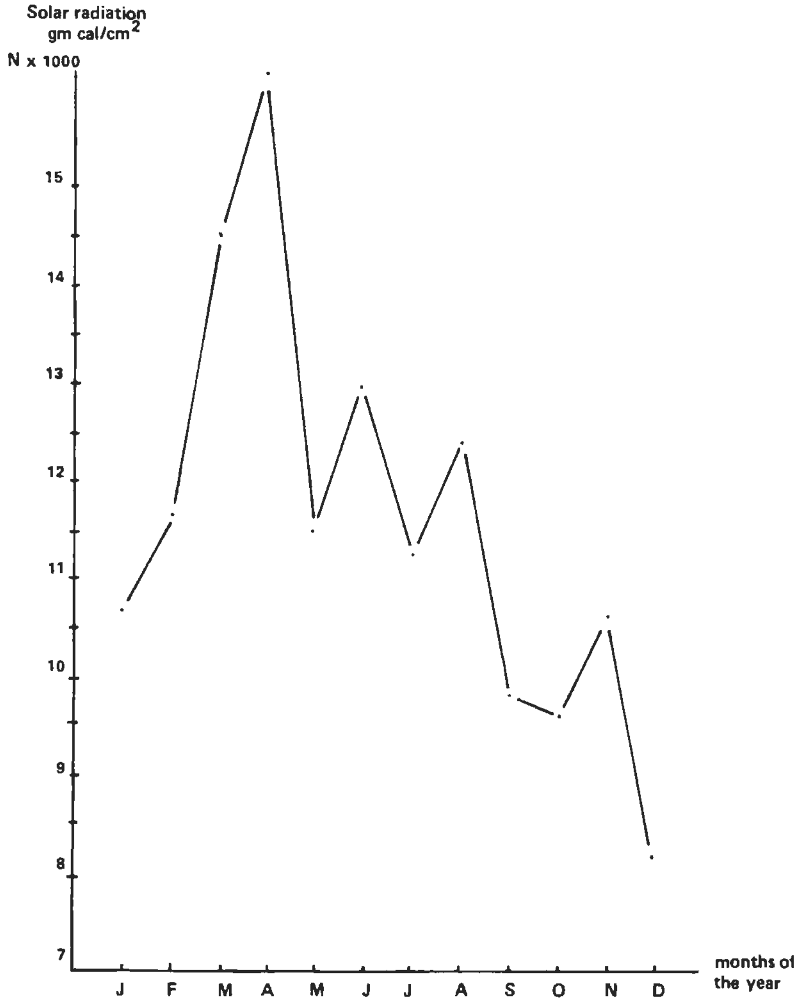


**Fig. 3. Amount of solar radiation in gram-calories per square centimeter per month (Los Baños).**

the start of the series of studies which is the basis of the present review. Our interest in photoperiodism in plants reached its peak in 1965, when I transfered from Los Baños to Diliman.

## Publication of results

As mentioned earlier, our data on the erratic flowering of the variety Elon-elon were kept idle in our file. In the chaos of 1944-1945, they became a casualty of the war. If we had taken the trouble of publishing our results in 1943, we would have called

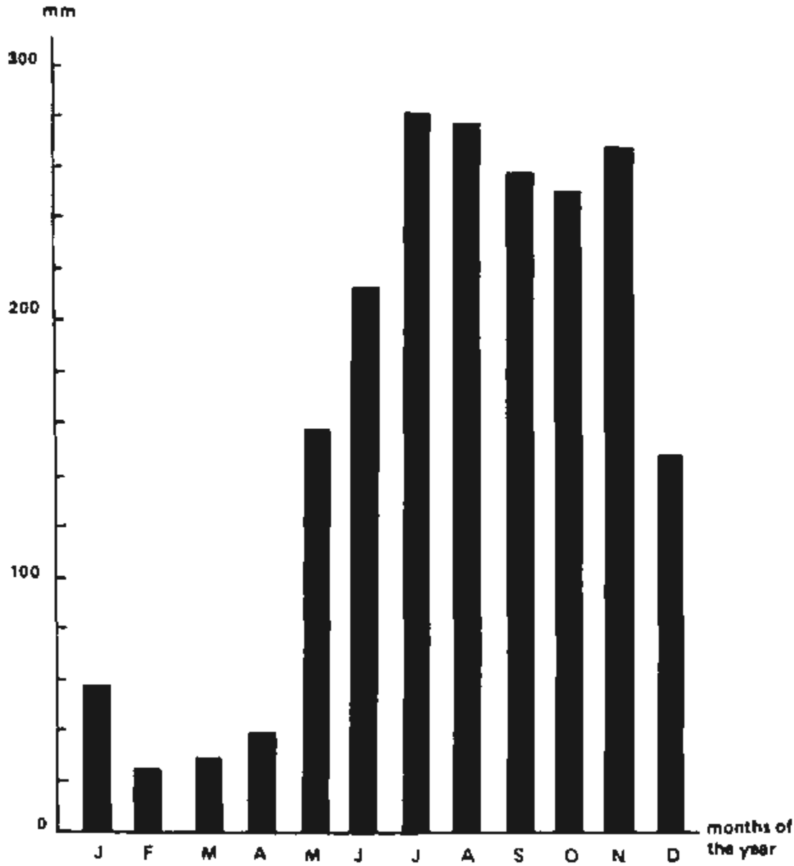


**Fig. 4. Rainfall in mm in various months (Los Baños)**

attention for the first time to photoperiodism in rice. It was only in 1945 that Sircar and Parija published their results on the subject, and they designated the phenomenon as vernalization. Two factors contributed to our failure to publish: (1) because of the war turmoil, the scientific journals ceased to publish; and (2) we missed the implications of our data. We should have published our results even if we could not, as yet, see any immediate or apparent explanation for them. Then we would have attracted curiosity to the peculiar effect of time of planting on the flowering of rice.

Quite apart from consideration of priority and the perpetuation and/or propagation of information, publication of results has certain inherent benefits. For instance, in the process of preparing results for publication, we incidentally study, review and interpret our data. This affords an opportunity to note the weak points

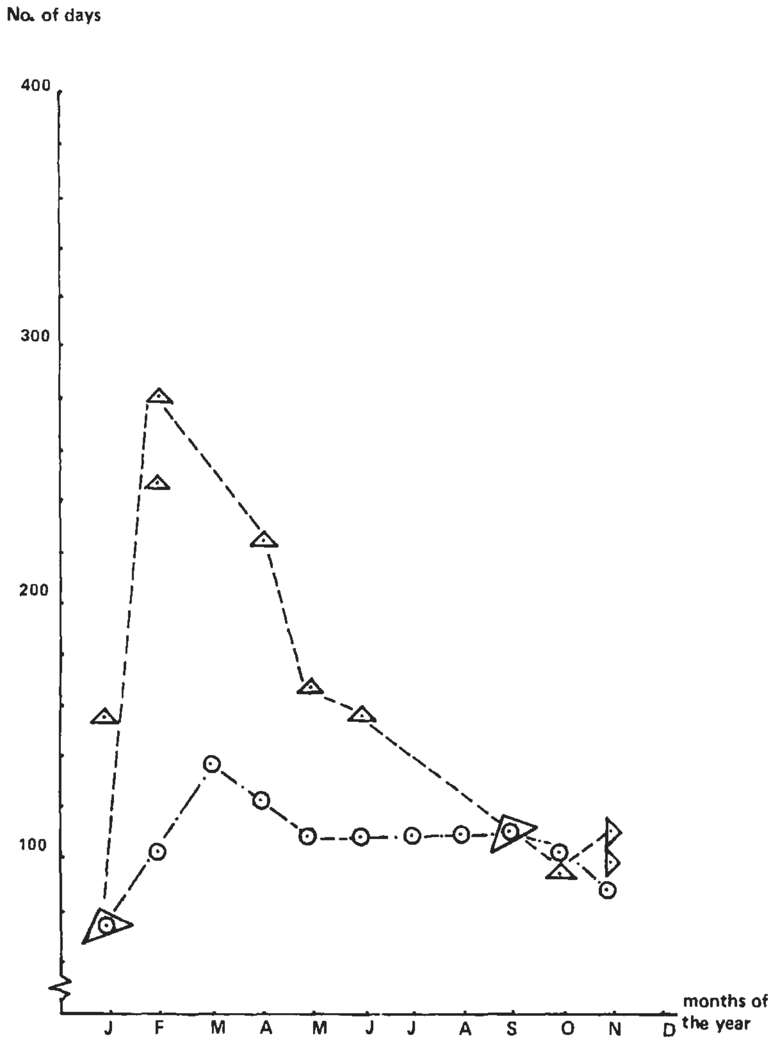


**Fig. 5. Number of days from planting to flowering of Inintiw (lower curve) and Elon-elon (upper curve) planted in different months.**

which need verification. Furthermore, the implication of the data may lead us to form a new hypothesis or modify a current one.

Again, to relate our results to the body of extant information, we may feel the need to study the literature on the subject. Hence, we broaden our outlook and, perhaps, find opportunity to improve on what we (and others) have done before. It is a truism that in science we stand on the shoulder of those who came before us.

An incidental benefit from a research paper is that it serves as a vehicle for the propagation and promotion of local research and researchers. This is least appreciated in the local scientific circle. Filipino researchers have a penchant to cite in their articles the studies made by Europeans and Americans, hardly, if at all, citing those made by Filipinos. This is perhaps an attempt to put on a mask of erudition — others call it colonial mentality. One good example of narrow nationalistic patronage in citation is to be noted in the paper of Yoshida and Parao (1976). They cited 50 (out of 69) of Japanese origin; 17 of the remainder were published by the International Rice Research Institute — many of which were co-authored by visiting Japanese scientists. They did not cite any study on rice from the U.P. College of Agriculture — not even the pioneering study of Peralta. Perhaps they felt that it was not worthwhile.

This matter of setting standards for worthy research and research papers is rather moot. Most present-day scientists ignore papers published in so-called developing countries because the data were secured with outdated equipment. Furthermore, the experimental conditions were not well controlled. Unhappily, to come up to their standard, we have to establish and run our laboratories through a pipeline, as it were, from the developed countries. (I facetiously call this, "economic colonialism through science.")

Lest I leave the impression that I am a modern Luddite, let me hasten to add that if we decide to establish an advanced laboratory we should attempt to supply at least part of its requirement. By moving to dispense with the "pipeline" we may yet succeed in upgrading local technology.

Well, so much for the rambling thought.

If we come to think of it, the primary objective in research is to advance the frontiers of knowledge. It is desirable to attain this objective with precision equipment; but the latter is not always essential. Thus, if Peralta's "haphazardly" obtained information is confirmed by Yoshida and Parao with the use of sophisticated equipment, why should we not credit Peralta for gaining the insight despite "non-standard" equipment and conditions? Let us recall that Einstein formulated his famous energy-mass equation without any experimental evidence. The supporting precise experiments came very much later. And yet people credit Einstein for his contributions.

**Further studies on photoperiodism**

Our realization that photoperiodism was involved in the erratic flowering of rice planted in different months may perhaps be considered as — i.e., can pass for — a synthetic discovery (in

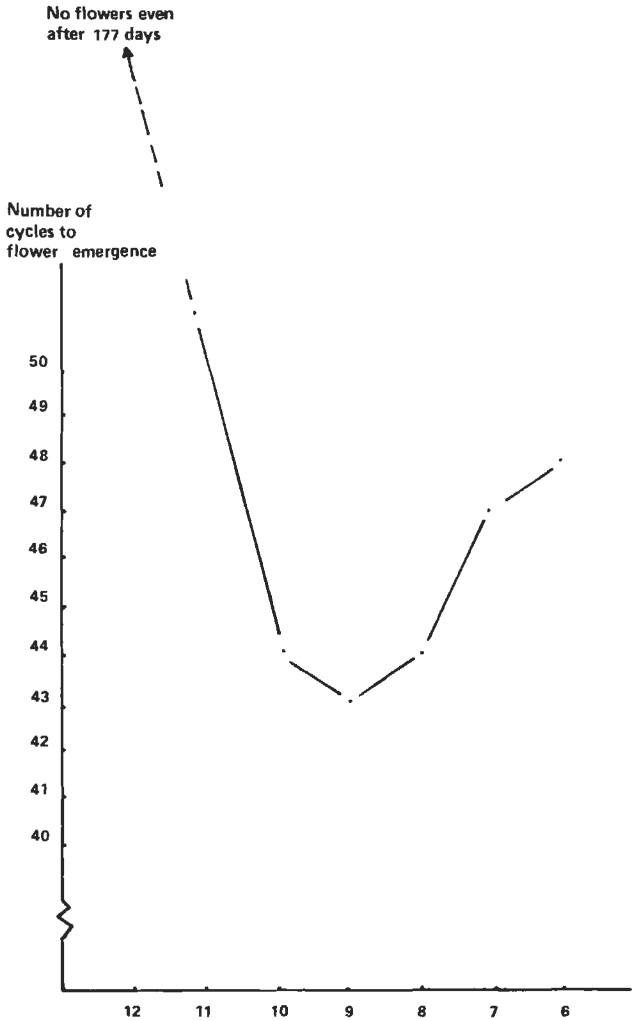


**Fig. 6. Number of cycles needed to effect flowering in Elon-elon variety of rice.**

line with Medawar's classification). If this were so, our subsequent studies on the effect of daylength on rice was a continuous dialogue between conjecture and refutation/confirmation hence, analytic.

First, we conjectured that rice might have a limit in daylight hours beyond which it would not flower — a so-called critical daylength. To find this limit, we subjected 45-day old plants to daylight cycles ranging from 6 hours to approximately 12 hours (natural day-length). Figure 6 shows that under normal day, no flower emerged even after 177 days. (The normal day in March, when the experiment was started, has about 12 hours of light; it gradually lengthened towards April, May and June.) At 11 hours of light, flowers emerged after 51 cycles. The number of cycles decreased as the daylength was decreased reaching a minimum of 9 hours of light. When the daylength was further decreased towards 6 hours, the number of cycles for flowering became inversely increased. Unhappily, the critical daylength was not established in this experiment; perhaps it lies between 11 and 12 hours of light. Although we missed on the critical daylength, we were able to speculate from the results that light could have two complimentary roles in flower formation: (1) it mediates in the elaboration of a substance (hormore) which triggers flowering, and (2) it helps form the plastic material (carbohydrates) which is the building block of the flower. In other words, light influences the form and substance of the shoot apex — the architecture and structure which underline all nature. The minimum number of cycles to flower-emergence obtained with the 9-hour daylight cycle indicates that, the optimum combination of the complementary roles of light occurs here.

This travel-log into the by-ways of thought and experience can be interestingly amusing. As Robert Frost said,

> The woods are lovely, dark and deep,
> But I have promises to keep,
> And miles to go. . .

In order that my talk would not deteriorate into a second-childhood tale, let me summarize by saying that through the process of conjecture and refutation/confirmation, we seemed to have established the following facts:

1. The stage of ripeness to flower is attained at the age of 15 days. However, the number a short-day cycle for flower induction decreases as the plant grows older. The optimum age for short-day treatment is 45-60 days.
2. If we schematize the process of flowering into (a) flower induction (b) flower and initiation and (c) flower development, shortdays seem to affect all the three stages. On the other hand, mild temperature (21°C) during the dark period seems to affect markedly only flower development. It can not replace short-days in flower induction.
3. Synthetic growth accelerators (NAA) and growth inhibitor (MH) seem to have supplementary effects on short days.
4. The youngest, fully exserted leaf seems to be most responsive to short-day treatment. And,

5. The flowering stimulus does not seem to migrate to other non-induced tillers.

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# DISCUSSION ON
# THE RESPONSE OF RICE TO LIGHT

**Benito S. Vergara, Ph.D., Discussant**

I would like to comment on a point Dr. Velasco made regarding the non-use of Philippine scientific articles in many technical papers he has read. We should analyze this problem and make the necessary campaign, and exert effort to rectify the problem. We certainly would like to hear the solutions to this problem from Dr. Velasco who has thought about it for many years. (I remember his concern about this problem more than 10 years ago when he attended the Pacific Science Congress).

A simple analysis of the problem may give the following reasons for infrequent citation of Philippine publications:

1. Philippine journals are not widely circulated. Even if they are, many students, scholars and scientists are not aware of their existence. What can be done about this? Are Philippine scientific journals abstracted by abstracting services? A study of IRRI publications, a relatively young institution, showed that a great majority of papers on rice published in the last 10 years cited IRRI publications.

2. In writing reports and scientific papers, scientists tend to go through the literature of the last 10 years only. This is so because literature dating earlier than 10 years back are either difficult to retrieve or expensive to retrieve. For example, most of the computer systems in Europe and USA will give you citations on a topic only up to the last 20 years. Depending on the research topic, most scientists will not spend more than a month going through the literature. We are all guilty of this. But is it always necessary to make a very exhaustive search? In many cases it is almost impossible.

3. Filipino scientists do not exert effort to cite Filipino publications in their papers. A paper published in 1919, like that of Dr. Peralta's, can be brought to the attention of young scientists only if it was cited in a recent paper or review. On the other hand, a look at a Russian paper will show that 99% of their citations are Russian. Similarly, the Japanese, Indians and Chinese have the same tendency. . . . but this is not so with the Philippine scientific papers.

4. The problem may also be the result of non-confidence in the data obtained by local scientists, as pointed out by Dr.

Velasco. I am not sure how serious this problem is. But, I do have full confidence in the scientific papers coming out of Los Baños. And my confidence is shared by many foreign scientists. I have not heard of any one questioning the reliability of their data.

There are varied reasons for the problems pointed out by Dr. Velasco — let us think of how we can contribute to its solution. And I hope the Academy can plan a program to help in getting our scientific papers better known not only locally but by the outside world as well.

**Reynaldo A. Tabbada, Ph.D., Discussant**

I will limit my discussion to photoperiodism itself which I think is the thrust of Dr. Velasco's paper. Since the 1920's when the phenomenon was discovered, all attempts so far to trap the product(s) of the photoperiodic stimulus have failed for one reason or another. From the 1920's to the 1950's, most studies have substantially described the gross morphological responses of different plants and classified these into different response groups — as short-day plants, long-day plants and so on. From the 1950's up to the present, plant physiologists have intensely pursued work on possible internal mechanisms and processes that may explain the photoperiodic behavior of flowering plants. Now, evidences, for example, have been established linking the photoperiodic behavior with the phytochrome system, a plant pigment. Other studies also have invoked the participation of hormones as a possible intermediaries in the flowering behavior of photoperiodic plants. The involvement of protein as well as nucleic acid metabolism in the photoperiodic response is also well documented.

But beyond these concepts, we really do not know the basic mechanism involved in the photoperiodic responses of flowering plants. In the case of the rice plant, Dr. Vergara's review of practically all available literature on the subject matter strongly indicates that most studies are basically descriptive in emphasizing the morphological responses when rice cultivars are subjected to varying degress of photoperiodic treatment, number of photoinductive cycles and so on. It is quite obvious then that such remains to the worked out. For one, we have not looked into what is happening inside the recipient of the stimulus, like the tillers. What events are taking place there? What are the structural changes that follow the perception of an inductive stimulus that would describe the photoperiodic nature of a specific cultivar. As pointed out in Dr. Vergara's review, such studies in the rice plant apparently have not been pursued for reasons I really don't know.

**Geminiano de Ocampo, M.D., Discussant**

I do not know why Dr. Velasco chose a physician to discuss his paper on rice culture. It might be because of my book on a System of Medical Research which is applicable to all life sciences. Biological research should start with the proper questions based on previous observations — clinical, laboratory or field, Theoretical and basic research should also start with a question even without any previous observation. In a research proposal, objectives are not sufficient. Specific questions on the objectives are necessary. The formulation of the proper question is one of the most difficult phases of any biological or other forms of investigation. If the proper research question is the starter of any worthwhile research, comparison and measurement are the crux of the expedition. Serendipity and discovery are in a different category of investigative endeavors. A discoverer need not be a good researcher. The results of an investigation are valid and valuable if they have answered the starter question or questions.

I recall that in 1946 soon after World War II, Dr. Velasco and I were among those sent to the U.S.A. for further studies. Dr. Velasco has a regard for a physician in healing a patient. In truth we just help the patient to recover from an illness. It is really the Almightly that heals.

The history of the proper questions on a research problem is very important. If photoperiodism is a concept in plant science, the proper questions on it should be framed before embarking on any investigation on it.

The application and implication of the results and conclusions of any investigation should be pursued further separately. Sometimes a researcher stops at its application but fails to grasp and pursue its implication. Sometimes the application of a concept is prematurely investigated without clarifying its basic aspects. Here is where applied basic research is needed. The research on laser and its application is a good example of this.

Literature research on a research question is very important. The research organization in the Philippines must confront this problem. Nationalism in biological and other areas of Philippine research should be promoted. Setting Philippine standards in all areas of our research is a challenge. Another problem of research in our country is acquisition of the proper instruments and the training of man to handle them.

Einstein and most Nobel Prize winners had concentrated on theoretical research. Basic research encompass theoretical research. We should engage more in directed applied and directed basic research. I am glad that the new science community leadership has set 15% of our research support towards basic research.

I know little about plant research but as in medical research there should be some classification of the meaning of "growth". In our research training more emphasis should be placed on semantics and framing of research questions.

I have formulated two basic concepts in ophthalmology and medicine, that of "self-renewal" in life and death and the postulation of five biological pathways, viability, development, differentiation, protection and proliferation. The phenomena of growth, flowering and fruit bearing are different activities in these different biological pathways. I hope these concepts on the subdivision of the genome will attract the attention of plant and animal biologists. I invite the biological groups of the Academy to scrutinize this concept. I would be very glad to expound on them in any appropriate place and time.