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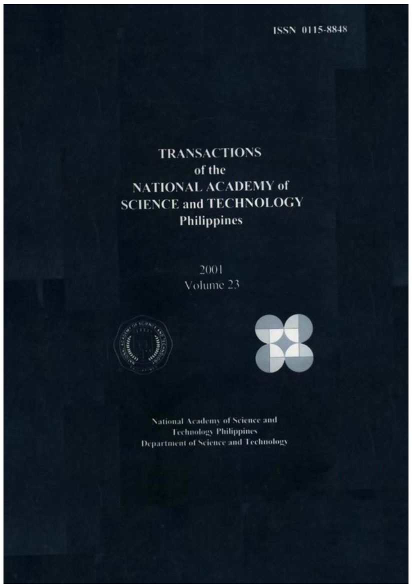

A Science Career in Rice

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A SCIENCE CAREER IN RICE

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ABSTRACT

The importance of focus in one's science career is presented through the development of rice with high yields and tolerance to adverse environment. The role of Plant Physiologists at IRRI in the green revolution is presented. Morphological and physiological basis of high yielding plant types; increasing grain yield potential; tolerance of rice to low temperature at different growth stages; flood tolerance; and development of screening methods for adverse climatic conditions are discussed. The present high yielding rice varieties have reached their potentials. The physiological and morphological considerations for the new plant type for higher grain yields is also presented.

Teachers have played important roles in the careers of many of you. I am not an exception. My high school teachers in biology at the University of the Philippines (UP) made science so interesting that I decided early on to go to science. This was enhanced by my professors in Botany and Zoology at UP. Prof. Consuelo Asis' excellent lectures were partly the reason I majored in Botany. Dr. Gregorio T. Velasquez, a National Scientist, nurtured me and set the example for my work ethics. It was difficult for me to study Botany instead of Medicine. My parents were keen on my being a medical doctor. I was already accepted in the College of Medicine; premed then was a two-year course. But I continued my bachelor's degree instead. One can decide one's career but many unforeseen things can happen. After graduation I enrolled for a Master's degree. After one semester I was asked to go to Hawaii with less than a month of preparation. The University of Hawaii awarded a graduate assistantship to one of my classmates, Mateo Sanchez, who graduated *magna cum laude*. He, however, decided at the last minute to enter the priesthood. Hawaii was desperate for a last minute replacement and Dr. Velasquez recommended me.

My ambition then was to teach in UP. I wanted to specialize in Taxonomy but UP already had a specialist on the subject. My next choice was Genetics. Again somebody was already then specializing in the field. I ended up in Plant Physiology.

From Hawaii I was fortunate to get a full scholarship at the University of Chicago for a PhD. That year they had 12 new scholarships available. These unplanned events would see me well in the future. My thesis was on photoperiodism or the response of the plant to the length of day. I was not quite sure how this study was going to contribute to my future work in the Philippines or to at least land me a job. After finishing my degree, my adviser offered me a job, but told me to go home if I intended to settle in the Philippines eventually. He told me to start my career in the Philippines early. That I did.

During my younger years, I heard a seminar by Dr. Jose Velasco who is now a National Scientist. He mentioned about the sad situation in international conferences, especially in Asia where Filipino scientists were not sought after, for their opinion. If there is a problem about rice, corn or coconut, participants do not seek the comments of the Filipino scientists. He pointed out that the problem was in the way we set our goals in our research. We conduct a little of this he said, a little of that, with no concentrated effort or consistent subject to work on. This stuck to my head .... Focus, focus, focus. When I came back from my studies, the International Rice Research Institute (IRRI) was looking for someone to study the photoperiod response of the rice plant. My thesis was after all useful.

Rice physiology then became my focus and further focused on growth and development.

Most of our traditional rice varieties flower only when the days are short (Fig. 1). When planted at the start of the monsoon season in June to July, they will flower in September to October in time for harvest during the start of the dry season. However, with the availability of irrigation water, a dry season crop with higher yields was possible. Most of the traditional rices when planted in March, April and May, still flower only in September to October. A variety whose flowering is not affected by the daylength was needed, one that will flower after a definite growing period when planted any time of the year.

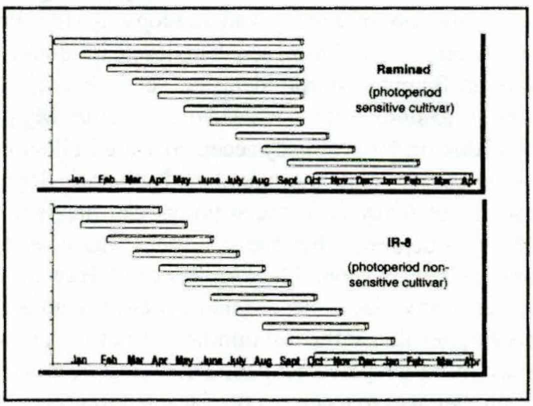
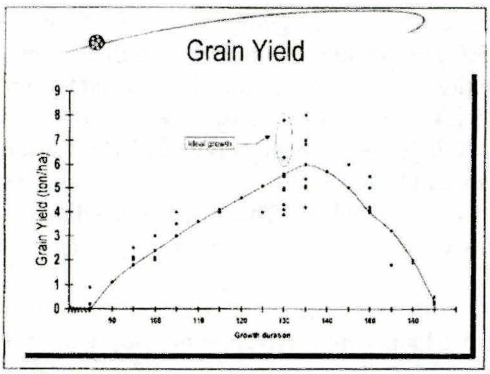


Figure 1. Days from sowing to flowering of photoperiod sensitivre and photoperiod non-sensitive varieties.

Our initial research was mainly focused in understanding the photoperiod response of the rice plant. Basic studies, as well as developing screening methods to identify cultivars with no photoperiod sensitivity, was one of our primary objectives. When we had accumulated sufficient information and data, we published in 1976 a bulletin on the 'Flowering Response of the Rice Plant' which saw several printings and editions. Photoperiod sensitivity was a problem in most rice growing areas of the world. In 15 years we experienced what Dr. Velasco was hoping for, for Filipino scientists. Letters were coming in inquiring about photoperiodism in rice and scientists were using our results in developing photoperiod nonsensitive cultivars.

The traditional rice cultivars generally had a growth duration of 150 to 180 days. This was relatively long. Can we shorten the growth duration? How short? Our findings showed that 130 days was optimum (Fig. 2): another trait the breeders could use as criterion for selecting advanced progenies. This time we were recommending to the breeders what to look for based on scientific findings although many of the better traits were already being used by the breeders … part of the art of breeding.



From the beginning the Plant Physiology Department of IRRI conducted research on plant type or characteristics of a plant that will produce high grain yields. One major characteristic needed was photoperiod non-sensitivity.

Another trait that was needed was the reduction in plant height to prevent lodging of the traditional rice varieties. This was the idea of the Director of IRRI then, Dr. Robert F. Chandler, a soil scientist. The Plant Breeders started breeding for short plant height which seemed to be a logical way to prevent lodging. Indica cultivars from Taiwan were used. In the mean time the Plant Physiologists were figuring out the physiological rationale for this trait. Shortening plant height alone increased the grain yield of rice dramatically. We also found that short plant height also meant less plant parts respiring and therefore more efficient plant. But how short do we want the plant? Decreasing the plant height would telescope the leaves to the base and would result in greater shading of the lower leaves. A certain spacing of the leaves is needed for better light distribution. An optimum plant height of around 120 cm was found optimum.

Shortening the plant height would also increase the panicle/straw from 0.15 to 0.20 of the traditional varieties to 0.50 in the new high yielding varieties. A panicle /straw ratio of 0.50 means 50 grams of panicle produced per 100 grams of straw. Increasing to 0.60 ratio was still possible but the resulting plant was small like 36 grams of panicle and 60 grams of straw. There was a corresponding large decrease in grain yield with further increase in panicle/straw ratio. This was a dead end for increasing the potential yield further.

Dr. Akira Tanaka, the head of the Plant Physiology Department then, was working on the nutritional as well as the respiration/photosynthetic aspect of the rice plant. He was also studying the role of every leaf on a rice stem and came up with the need for at least three leaves at flowering. This is also a very important morphological trait that one can select for and use as a criterion for a good crop at flowering stage. Although information was available for japonica varieties, hardly anything was available for indica varieties, the varieties planted in the tropics.

We know how many leaves are needed and the role of the different leaves at different growth stages but not the optimum tiller number. Research on tillering of the rice plant is a tedious process of tagging every tiller that came out. The rice plant may produce up to 50 or more tillers at the maximum tillering stage but most of these tillers die before the flowering stage. Results showed that the optimum tiller number was around 10 to 15 tillers per hill for transplanted rice at the flowering stage.

The Plant Physiology Department worked on light distribution within the rice canopy, the importance of leaf angle i.e. vertical, 45^{o} or horizontal orientation and if it varies with the position of the leaf. This was also a tedious job. Fortunately, the Philippines has many excellent farm workers and highly qualified research aides to help in the research.

The harvest index or panicle/straw ratio, spikelet sterility, optimum number of spikelets, etc. were also looked into. All the above physiological and morphological traits were used by the Plant Breeders in selecting for high yielding cultivars.

By 1969 the following traits were proven to be necessary for high grain yield of rice: short stature (90 – 110 cm); short, erect leaves; medium to heavy tillering (10 to 15 tillers per hill); and a growth duration of 130 days.

It was very gratifying to have contributed to the production of the first group of 'miracle rice' (IR8 and IR5) within a period of seven years. Even if all the glory went to the Plant Breeders, we in Plant Physiology had that inner satisfaction and pride that we played a very important role.

After the IRRI-bred high yielding cultivars were introduced to other countries and marginal areas, some problems which were not anticipated came up. The new cultivars also had many limitations besides susceptibility to biotic stresses. The new cultivars had little tolerance for complete submergence in water, ability to rapidly elongate in deepwater, or tolerance to low temperature at different growth stages. Those were our next challenges.

Our group worked on these environmental factors including the morphology and anatomy needed, and the physiological bases for tolerance. It was exciting because most of our basic findings were being reported for the first time. By this time we also had more trainees, scholars, and post doctoral fellows. They all contributed to the body of knowledge necessary for understanding the rice plant and in the development of screening methods to select for tolerant cultivars.

Based on these findings, we developed screening methods for flood tolerance at different growth stages but concentrated at seedling stage where we could screen the germplasm and the breeding lines by the thousands. The method was tried and adapted to local conditions in Thailand, India, Bangladesh, Indonesia and other countries. Together with the national rice programs, we screened thousands of cultivars and identified the useful ones for possible use as donor parents. Later, the progenies of the crosses made were also screened in their respective countries.

Many cultivars that are now being used are tolerant to flood from 7 to 10 days. Like the Plant Breeders, it was also a delight for our team and a great satisfaction to see results of our efforts - new cultivars with traits incorporated for submergence tolerance and screened by our group and collaborating scientists. Several international workshops and conferences were convened on deepwater rice and flood tolerance.

Our travels to Asia showed the results of our efforts on flood tolerance, not only on the cultivars developed, but for the facilities set up and the personnel we have trained, working on this trait.

When the high-yielding varieties were introduced in high elevation and high latitude areas, other problems were reported. Tolerance of other physiological factors were also needed by the rice plant. Low temperature tolerance at different growth stages was one. The japonica cultivars of Japan generally have cold tolerance but this is not the type planted and preferred in other parts of Asia. Also, they are susceptible to blast disease of the tropics. However, the indica types generally have no cold tolerance. Their growth duration is extended and the panicles do not exert out of the leaf sheath resulting in high sterility. A search for cold tolerant cultivars from the indica type was needed.

A screening method had to be developed at seedling stage, tillering stage, panicle initiation, and flowering. In some rice growing areas, tolerance is needed at the beginning of the growing season only, while in most cases low temperature is a problem at the reproductive stage. In mountainous areas, low temperature might be a problem throughout the growing season.

Our collaboration and more than 20 years of summer work in Korea have produced cultivars tolerant to low temperature. A new facility was built by the Korean Government for cold tolerance screening. My research assistant worked in Korea during summer and the Korean scientist came to IRRI during winter. We started screening the cultivars from the mountainous area of the tropics and subtropics. Some of the identified cultivars were introduced directly to sites in Nepal, Burkina Faso and some mountainous areas through the International Rice Testing Program of IRRI, a highly successful project of UNDP. Visiting the mountain areas of Banaue, Kashmir, Kathmandu, Bhutan and other Himalayan areas was not only inspiring but gratifying when one sees the progress that has been made on cold tolerance.

During the early years at IRRI, we were also involved in training extension workers. Fortunately I did not have any administrative responsibilities. I had time for my interest in ornamental plants which provided me with meaningful activities before and after retirement. I had time to write a primer on growing rice which was later translated into 40 languages and printed in 48 editions in 20 countries. It was the most widely translated book in Agriculture. This is another interesting adventure since IRRI initially was not interested in publishing the book. Eventually IRRI received two international awards for this book.

During the eighties rice yields have reached a ceiling of 8 to 10 tons per hectare. Breeding from 2 tons to 8 tons grain yield was relatively easy. This was reached in ten years during the early sixties under experimental conditions. But further increases when you are near the ceiling is more difficult. Where do we go next?

Transplanting rice is tedious and there is a shift to direct seeding now that weeds can be controlled better at seedling stage. Is there a need for a different plant type for direct seeding? How about for higher yield potentials? A rethinking had to be done.

Increasing the number of panicles per unit area, spikelet number, or weight per grain and decreasing spikelet sterility have been tried but the optimum values have already been reached. Increasing the size of the grain had also been tried but resulted in poor spikelet filling. Increasing photosynthetic ability or decreasing respiration was being research on by other scientists.

A visiting scientist whose application was rejected by two other departments in IRRI ended in our laboratory. By luck we had the same idea about the possible way to increase grain yields. We thought we have found a possible increase of 20 percent (?) in grain yield by increasing the density of the grain. How do you get this increase in grain density?

If you increase the spikelet size to get large rice kernels (i.e. greater than the size you are familiar with), the result is a spikelet that is usually partially filled or 60 to 70 % filled (Fig. 3). The filled spikelets or grains will float on water. Apparently the delivery system of the rice plant is unable to fill up the spikelet in 20 days. This is the number of days from fertilization to maturity of the spikelets.

Going back to the optimum spikelet size, a closer examination of the grains showed that varietal differences and differences within a panicle exists. Many spikelets are not well filled. Within a panicle, an increase in grain density of 20% was possible i.e. more starch per volume resulting in a higher density of the grain.

At that time, we had a visiting scientist, three PhD and two MS students, and a full time research assistant working on this problem of increasing grain density. Again, I would like to stress that a scientist in the Philippines is very fortunate because there are many highly qualified field and laboratory workers. They counted and measured thousands and thousands of individual grains.

To study grain density, we examined the location of well-filled grains and empty spikelets in the panicle, the delivery system of the rice plant, the vascular

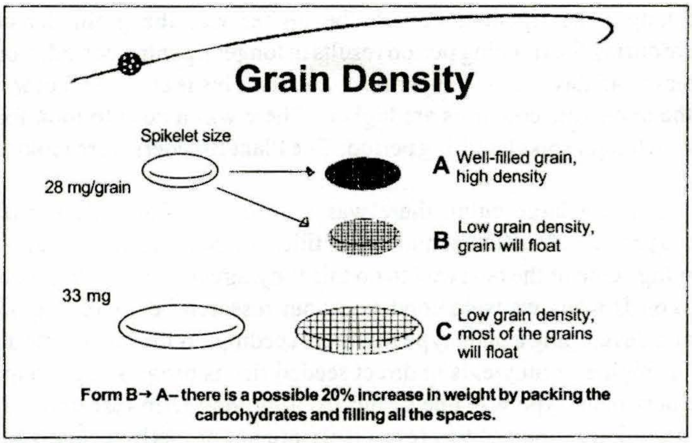


Figure 3. Grain density of medium and large grains

bundles, panicle branching, and even the abscission layer of the spikelet. Our findings showed that the desired large panicle has to have more primary branches rather than secondary branches since grains from the secondary branches generally had poor grain filling (Fig. 4). The number of primary branches was correlated to the number of vascular bundles going to the panicle. It is also possible that the more vascular bundles in the culm, the better was the delivery system. Therefore there was a need for large diameter culm.

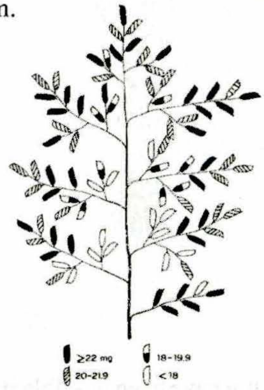


Figure 4. Distribution of different grades of grains in a panicle

To increase grain yield, we can increase the weight of the panicle by increasing the number of spikelets and have the spikelets well-filled. A sturdy culm to hold the panicle with concomitant large number of vascular bundles for better delivery system of the photosynthate was needed. To have large diameter culm, only a few tillers per plant should develop so that the energy will be used for developing the size of the culm rather than for producing more tillers. This idea was different from the current plant type of relatively more but smaller tillers.

The longer the ripening period, the higher was the grain density. Low temperature during the ripening period results in longer ripening period, from 30 days in the tropics to 45 days in the temperate countries. This is also one factor why grain yields in the temperate countries are higher. There was a need to look for possible cultivars with longer spikelet filling period. The Plant Breeders were looking into this with little success.

To produce a large culm, there was a need for a low tillering plant type. However, to produce a sufficient number of tillers or panicles per unit area, we need dense planting. One of the best way to do this is by direct seeding. We were actually hitting two birds when we were conducting our research i.e. increasing grain yield potential and developing a plant type for direct seeding. With various modifications, breeding for higher grain yields in direct seeded rice is progressing along this line.

The new plant type was one of our exciting long term research (Fig. 5). My colleagues and I are proud of this (even if we are not properly recognized at IRRI). Our paper "Enhancing grain yield potentials in rice by increasing the number of high density grains" was selected as the best paper in 1986 by the Crop Science Society of the Philippines.

Figure 5. New plant type

All this research would not have been possible if I succumbed to the temptation of higher position and salary. My success in rice research was not luck, I studied and prepared for it. A rare opportunity was given to me and I was able to use it because of my academic preparation.

The excellent support I received from IRRI, my long time research assistants like Romy Visperas, Aurora Mazaredo and George Pateña, students, post doctoral fellows, visiting scientists and colleagues will always be remembered especially in my twilight years. Many great Filipino scientists influenced my life and research and I am grateful for the wisdom they gave me.