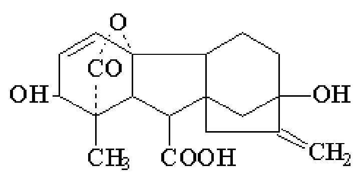
Discovering Gibberellin Helped the World to Reconnect after World War II

World War II not only shattered international relations but also the international diet. Food and other essentials were shipped to the military to keep up the war effort; whatever was left at home was rationed. Any diseases infecting crops came as a huge blow to the already tumultuous situation as home and on the warfront. In Japan, where military expansion in the 1930s had created a shortage of mineral resources, infected rice crops during World War II affected the population intensely. Rice is a staple of the Japanese diet; reduction of rice was detrimental to the delicate social balance.

A rice disease/fungus, *bakanae* (Japanese for "foolish seedling"), made rice plants spindly and weak, unable to produce any chlorophyll in rice-plant leaves, causing infertility. These plants could not produce edible grains; eventually they became too weak to support their own weight, toppled over, and died. Rice-crop yields declined considerably during the war years, causing starvation. Because pertinent technology and research funds were in short supply, failure to understand what caused this malady produced much misery.

Many years prior to World War II, Eiichi Kurosawa[i], a Japanese plant pathologist, reasoned that maybe some metabolite of the plant-disease fungus was interfering with healthy seedling growth. After much trial and error, in 1926 he successfully obtained a filtered fungal extract which stimulated growth in both rice and maize seedlings without the accompanying infection seen in *bakanae*. Kurosawa examined this response and deduced that it was brought on by a heat-stable substance found only in places where the *bakanae* fungus was present. He called this substance *Gibberella*, which stimulated cells to elongate. His observations were replicated by other investigators in Japan; eventually they and Kurosawa determined the chemical properties of the fungus. Although their work was published in Western languages, their discoveries did not arouse interest outside of Japan. It is ironic that at the same time, auxins, another group of hormones, had been detected in fungi.

With the help of Teijiro Yabuta, Takeshi Hayashi and Yusuke Sumiki, Kirosawa extended his work on *Gibberella*. In 1938, Yabuta and Sumiki isolated two crystalline substances they called 'gibberellin A' and 'gibberellin B'. Later, the terms were reversed because gibberellin A was shown to be inactive .The researchers continued to investigate the chemical nature and biological properties of *gibberellin*, but culturing large quantities of the fungus was difficult. Due to World War II, publication of the results also failed to reach Western readers. Figure 1 shows the chemical structure of Gibberellin.



[ii]

Figure 1: Gibberellin ($C_{19}H_{22}O_6$)

In Japan, frequent bombings made consistent research difficult. The war had brought a shift in priorities, and adequate material for research was hard to find. Also, there was the ever-present fear of leaking out any scientific information that the Allies could have used to their advantage, or worse, for chemical/biological warfare. Hence any research done during the war was kept secret; much of it was lost to bombings, fires, and war-caused destruction. Even if the research would have reached Western ears, there was always the chance that it may have been overlooked. Wars are about national pride; after Pearl Harbor, the West was not keen to support Japanese prestige.

Fortunately, the war had also stimulated interest in developing techniques for culturing fungi for production of antibiotics. In related antibiotic research, it was clear to researchers that hormones other than auxin were involved in plant growth and development. Hence, when abstracts of the Japanese work finally became available in the West in 1950, Western scientists wanted to exploit the Japanese discoveries. Any resentment garnered during the war was replaced with a need for renewal toward international cooperation. The needs of society were growing; growth hormones for plants provided a significant step towards improved agriculture and toward providing renewed national pride.

The first exploratory work on gibberellins in the United States was performed at the biological warfare center at Camp Detrick, Maryland, in 1950. In 1955, Stodola and his colleagues developed fermentation techniques for mass producing gibberellins and showed that the substance they had isolated was composed of two gibberellins, 'gibberellin A' and 'gibberellin X'. A year earlier, workers at the Imperial Chemical Industries Ltd (ICI) in Great Britain had obtained a new substance with similar biological properties (but different physical and chemical properties) called gibberellic acid. They were responsible for starting development work towards producing large quantities of gibberellins for experimental purposes for the first time. From then until now, many pharmaceutical firms all over the world have engaged in antibiotic research to produce gibberellins. [iii]

Gibberellins are created through the isoprenoid biosynthetic pathway, starting with mevalonic acid that is converted via dimethylallyl, isopentenyl, geranyl and farnesyl pyrophosphates to geranylgeranyl pyrophosphate (GGPP). The GGPP is converted to another intermediate, and the remaining steps consist of high-speed centrifugation, oxidation, and reaction with enzymes to create gibberellins. Both the amount and the type of gibberellins produced by the fungus depend on the genetic constitution of the strain and on fermentation conditions. Another method is to grow *Gibberella fujikuroi* fungus cultures in vats, then extracting and purifying gibberallic acid. [iv]

Researchers in both Japan and the West found that gibberellins stimulate cells to elongate. The over-accumulation of gibberellins in rice plants causes the stalks to elongate and to become thin because they did not have enough resources to support their rapid growth. Because gibberellin overcame seed dormancy, researchers focused on understanding the pathway(s) of gibberellin better to control cell growth in rice plants. Upon sensing a change in their environment, rice embryos secrete gibberellin that initiate a chain of events forcing cells quickly to divide and elongate. Seed dormancy in plants ends when conditions can support plant growth. Apparently the frequent war-caused violence created a fluctuating environment that confused embryos, forcing them to overcome seed dormancy earlier than desired. As a result, gibberellins are produced and cells elongate; but without sufficient nutrition in a war-torn environment, cells would die. Consequently, populations that depend on rice suffered malnutrition; many died from starvation.

After the war, the environment stabilized, and Japanese farmers began using gibberellin to increase rice yields. Many different gibberellins are present in plants; each plant requires a unique amount to grow. Rice contains fourteen gibberellins. Usually, gibberellin is sprayed onto crops in small amounts because even the smallest amount may trigger excessive cell growth. Because farmers were also spraying their crops with herbicides, it was difficult to determine how much gibberellin could be applied without hurting the plant. The weather also influenced how much gibberellin was required, because gibberellic acid dissipates rapidly in moist soil.[v]

Understanding what caused rice plants to become spindly and weak was not only a remarkable scientific achievement; it was also part of a cultural evolution. After World War II, Japan cooperated increasingly with the West; as a result, Japan and Western countries were exposed to each other's customs. Introduction of new Western farm equipment allowed poor Japanese farmers to prosper while producing some essentials for the Japanese diet, allowing the population to increase. Not only Western farm equipment but also Western culture – clothes, movies, politics – were introduced to Japan, stimulating modernization. But with modernization came an effort to retain traditional Japanese customs, initiating a cultural struggle that persists today. As the Japanese people questioned their roles in their country's modernization, they developed a new world view. Writers and intellectuals took this new view to create a kaleidoscope of literature provoked by the wonders of Western technology.

Japanese and Western cooperation to understand the role of gibberellin in agriculture epitomized how science can help international communication. After the war, the world needed to be rebuilt, and there was little room for national pride in the face of hunger. Working together to feed their populations, prompted both sides to work more closely with one another, impossible during wartime. Cooperation provided benefits for all.

[i] Stowe, Bruce B., and Toshio Yamaki. "Gibberellins: Stimulants of Plant Growth." 3 Jan. 2009. JSTOR. UC Berkeley, Berkeley. Feb. & march 2009 <http://www.jstor.org/stable/1757477>.

[ii] "Gibberellic Acid." Agro-care Chemical. 17 Apr. 2009 <http://www.agrocare.com.cn/Products/Gibberellic%20Acid.htm>.

[iii] "Biotechnology of vitamins, pigments ... -." Google Book Search. 17 Apr. 2009 <http://books.google.com/books?hl=en&lr=&id=LXZpQgjDO08C&oi=fnd&pg=PR7&dq=%22Vandamme%22+%22Biotechnology+of+vitamins,+pigments,+and+growth+factors%22+&ots=bfgEx54wAq&sig=FFrSNCrPvrF1bivaGvo3jHZQVOE#PPA385,M1>.

[iv] Biotechnology of vitamins, pigments ... -." Google Book Search. 17 Apr. 2009 <http://books.google.com/books?hl=en&lr=&id=LXZpQgjDO08C&oi=fnd&pg=PR7&dq=%22Vandamme%22+%22Biotechnology+of+vitamins,+pigments,+and+growth+factors%22+&ots=bfgEx54wAq&sig=FFrSNCrPvrF1bivaGvo3jHZQVOE#PPA385,M1>.

[v] Welcome to the Turfgrass Information File. 17 Apr. 2009 <http://turf.lib.msu.edu/1950s/1958/580725.pdf>.