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Bangladesh, Factor 1: Plant Science

Bangladesh: Improving Crops Coupling With Abiotic Stresses

Bangladesh, located in South Asia, is considered one of the least developed nations in the world with some of the worst health and nutrition outcome data (Bangladesh Country, Web). It is the world's eighth-most populous country. Totaling 156.6 million citizens with an area of 147,570 km^2, it is the most densely populated non-island nation in the world (Harris, Web). Out of the 156.6 million people, 37 million-a quarter of the population-struggle with food security (World Food, Web).

The average household in Bangladesh consists of four-to-five people, usually with two parents and two-three children (Bangladesh, Web). Typically, families live in a small wooden shack with a tin roof referred to as "tin shade" in the slums outside of major cities. These tin shades provide little protection against the blistering heat in the summer and are easily destroyed by annual monsoon rains (World Food, Web). Despite the low unemployment rate of 4.5 percent, 43 percent of Bangladeshi live under $1.25 per day which is below the international extreme poverty line (Feed the Future, Web). Agriculture remains the most important sector of the Bangladesh economy, accounting for 19.6 percent to the national gross domestic product (GDP) and providing 63 percent of the population with employment (Bangladesh-Agriculture, Web). Although the government funds most schools, education in Bangladesh remains poorly developed. The literacy rate is 57.5 percent on average with a significant disparity between female (53 percent) and male (62 percent) (Education, Web).

More than 60 percent of Bangladeshi do not have access to basic health care, with one hospital bed for every 1,738 people and one doctor for every 3,200 residents (Halupnik, Web). Out of the small number of doctors in Bangladesh, 62 percent have little or no formal training. This is mainly attributed to low government funding with only 3 percent of the country's GDP going to health care (Who, Web). Poor sanitation conditions often lead to epidemic diseases such as tuberculosis, hepatitis and pneumonia. Bangladesh ranks in the top ten countries with the highest disease rate of tuberculosis (Chapter, Web). This is predominantly due to the poor economy and constant flooding, which makes it almost impossible for rural people to travel to major cities for cures. In Bangladesh, rice is the staple food, which is often accompanied with vegetables such as pumpkin, spinach or cauliflower, however these foods do not supply individuals with enough nutrients (Pitt, Web). Malnutrition has been a persistent problem for this poverty-stricken country. Bangladesh has one of the highest rates of malnutrition in the world, due to poverty, lack of access to agricultural land, and poor eating habits (Feed the Future, Web). Malnutrition is a leading cause of low birth weight, stunting, underweight, vitamin A deficiency, iodine deficiency disorders and iron deficiency anemia. All of which contributes to about half of all child deaths in Bangladesh (Dhaka, Web).

Bangladesh has enriched agricultural land. River deltas that bring silt and mud eroded from the Himalayan Mountains over millions of years nourish Bangladesh into a very fertile place (Harrison, Web). Rice, jute, sugarcane, potato, pulses, wheat, tea and tobacco are the main crops grown in Bangladesh. 72 percent of the overall agribusiness consists of the growing of these crops. (Bangladesh-Agriculture, Web). Traditionally, farmers maintain a sequence in crop rotation by switching out one crop for another after harvesting. For instance, they grow pulses, a grain legume, after rice. Leguminous pulses recover nutrients consumed by rice in the earlier season by fixing atmospheric nitrogen into soil. Thus, the land remains productive naturally without using many chemical fertilizers. Moreover, they apply cow dung or compost to the land, providing essential nutrients without damage to the environment. These traditional farming systems also aid in the biological control of pests and diseases (Abdul, Web).

Unfortunately, the fertile soil and good agricultural practice do not supply Bangladeshi sufficient food and happy lives. The agricultural development in Bangladesh is severely constrained by many challenges. In particular, crop production is frequently affected by flood, drought and salinity (Mondal, 2010). Among these abiotic stresses, flood is the most severe and frequent disaster that destroys the country's crop production. (Tingsanchali, Web) Bangladesh is prone to flooding due to being situated on the Ganges Delta and many tributaries flowing into the Bay of Bengal (Saifullah, Web). The coastal flooding paired with the bursting of Bangladesh's riverbanks is common and severely affects the landscape and society of Bangladesh. The devastating 1998 flood for example led to the destruction of up to 425 thousand hectares of rice and other crops, costing Bangladeshi farmers around $150 million US dollars (Floods, Web.). More importantly, about 75 percent of Bangladesh is less than 10 meters (33 feet) above the sea level and 80 percent is floodplains, rendering Bangladesh at a high risk of further widespread damage of flooding to the whole country (Bangladesh World, Web.). The flooding, which followed the same patterns for decades, is now different and often comes about 15 days sooner, right at the harvesting season (Islam, Web). This subtle climate change ruins harvests, threatens the ecosystem, and makes the already unstable livelihoods of people more vulnerable. Due to heavy reliance on farming, many people lose their food supply and income when crops are damaged.

With 28.8 million metric tons produced between July 2005 and June 2006, rice is the principal crop in Bangladesh (Bangladesh (05/07), Web). Because of its well-developed aerenchyma tissues which diffuses oxygen through continuous air spaces throughout the root and the shoot thus avoiding anoxia development in roots, rice is the only crop plant adapted to aquatic environments (Yanagihara, Web). However, complete submergence for long periods due to frequent flooding can dramatically affect rice yield and growth. Flood water limits gas diffusion and light penetration. Most rice will die if it is fully submerged for more than three days (Lebwohl, Web). Fortunately, scientists are making efforts to understand how plants deal with flooding and breed flood-tolerant plants. In the past two decades, a scientific research team led by Dr. Pamela Ronald at the University of California at Davis, has isolated a complex locus of three genes mediating tolerance to flooding and submergence in rice. These genes, called SUB1, encode ethylene response transcription factors (ERFs). Transcription factors are proteins which determine which genes are "turned on or off" in the genome. They bind to DNA, or to proteins within a DNA-binding complex, and can promote or block expression of genes that encode enzymes, thus making the genes less or more active (Transcription, Web). Because SUB1 encodes transcription factors, it suggests that SUB1 controls plant submergence tolerance through regulating its target gene expression. Importantly, overexpression of one SUB1, SUB1A, which is up-regulated rapidly in response to submergence, conferred robust tolerance to flooding in rice (Ronald, Web). This work not only revealed an important mechanism for how plants control tolerance to environmental stress, but also sets the stage for generating flood-tolerant rice varieties.

Dr. Ronald's group is collaborating with the International Rice Research Institute to introduce the SUB1A gene into agronomically important rice varieties (Septiningsih, Web). Bangladeshi scientists can introduce this gene into their local rice varieties with high yield, good quality and adaption to local climate. This could be done by two approaches; molecular breeding and genetic engineering. Molecular breeding is a traditional breeding assisted with molecular markers, called marker-assisted selection. Markers are the traits determined by allelic forms of genes and can be transmitted from one generation to another (Pocket, Web). This breeding could be done by keeping crossing SUB1A containing plants with Bangladeshi local rice varieties using markers linked with SUB1A gene to select SUB1A positive plants. This breeding program is widely practiced by breeders and accepted by the public for improving various traits of different crops. However, it takes four to six generations to reach a pure form of variety combining SUB1A gene and other good genes in Bangladeshi rice. On the other hand, genetic engineering provides an alternative and fast way to introduce a gene into an organism. This is commonly known as genetically modified organisms (GMO) (Genetic, Web). Genetic engineering is similar to molecular breeding in that they both change the genetic material of an organism. However they differ in that genetic engineering is done through direct introduction of a foreign gene into the host genome through certain laboratory techniques without breeding (What, Web). Thus, it is much faster and more manipulatable than a breeding program. However, GMO also raises concerns for many people since there are some theories about gene floating and toxicity of a foreign gene of GMO. Notably, no concrete scientific evidence exists that GMO negatively affects human health (Crow, Web). GMOs may not be universally accepted culturally, however the Banlgadeshi government is open to using GMOs. Ultimately, it completely depends on Bangladeshi people and which method they choose to generate flood-tolerant rice. The SUB1A gene, introduced through genetic engineering, was tested by a handful of farmers in Bangladesh and the results were promising. Rice was more tolerant to flooding and was reported by some to have a better taste (SUB1, Web).

As previously mentioned, the change of climate results in flooding which comes right at the harvesting season. The challenge is that rice is not ready for harvesting before monsoons. However the planting season cannot be moved earlier because the weather is too cold for rice to grow. If the farmers harvest the rice 10 to 15 days before rain season; this will avoid the flooding damage. This could be achieved by shortening the life cycle (from germination to maturity) of rice. Rice life cycle can be broken up into three stages: vegetative (germination to panicle initiation), reproductive (panicle initiation to heading), and grain filling and ripening or maturation (heading to maturity) (Leonards, Web). On average it takes three to six months for rice from germination to maturity. Early maturing is usually caused by early flowering. Since rice yield is mainly determined by the photosynthesis after flowering, early flowering plants reduce life cycle, but do not significantly affect yield and quality (Moldenhauer, Web).

A group of scientists at the University of Wisconsin-Madison discovered a gene that controls flowering, called FLOWERING LOCUS C (FLC). Mutating this gene allows plants to flower earlier (Zhang, Web). Scientists from PhilRice have developed seven varieties of early maturing rice, one of which is the Sahod Ulan 2. In the rain-fed lowland and drought-prone areas, Sahod Ulan 2 yields about 30 percent more than regular rice (PhilRice, Web). Sahod Ulan 2 matures in 110 days and is also resistant to blast, bacterial leaf and sheath blights, white and yellow stem borers, and green leafhopper (PhilRice, Web). Bangladeshi scientists could introduce FLC mutation in their varieties, test the fitness of Sahod Ulan 2 in their country and ultimately breed early maturing Bangladeshi rice varieties.

In addition to improving crop performance to flood, efficient flood management is another solution to increase crop production. The Bangladeshi people can plant vegetation that take up a lot of water such as bamboo, banana, hogla and kolmi around their houses. These plants suck up the water and keep the soil more intact. Many plants can be grown locally anywhere, protecting against flooding in both urban and rural areas. Another way citizens can attain food security is by building portable houses and shelters for animals. When flooding occurs, the livestock that is critical for a family’s welfare can be picked up and moved to a safe place inside the house, which would prevent the drowning of these animals and keep the water free of many sicknesses that animals carry. Building flood resistant houses provides an alternative strategy for Bangladeshi people to fight with flood. One way to improve housing conditions is to incorporate different construction changes. This solution may not be available to everyone due to the expense required to attain the materials, however it is generally available to many Bangladeshi people. Jute panels can be used for walls, which is a cost effective way to have strong but easily replaceable defense against the elements. Another way is to build the houses on plinths. These are stilts built from soil, a little cement, stones and brick. The plinth levitate the house and prevent damage from flooding, unlike the traditional houses that are easily washed away. Lastly, people can also tightly bind the walls to an internal skeleton structure of the house by using a network of notches and holes (also referred to as the clam system). All of the strategies mentioned above can help the house resist the strong winds and rains. (Adapting, Web). The Bangladeshi government can easily provide small amounts of funding to pay for the small parts (nuts and bolts) that can dramatically change the life of an average Bangladeshi. A more challenging method is to build dams, reservoirs and levees. Levees help reduce the chance of rivers spilling over and causing flood. Dams and reservoirs serve as protection against the flooding waters. Dams can have flood-control reservations, in which the level of a reservoir must be kept under a certain point to allow a space which floodwaters can fill.

Surprisingly, in the flooded country of Bangladesh, drought is another problem in the northwestern region. Flood and drought often come hand in hand. Rice suited for rain and wet cannot grow in northwestern Bangladesh where the monsoon rains do not reach. The previously mentioned SUB1A gene that makes rice tolerant to flooding, also makes more tolerant to drought stress. It seems paradoxical, but scientists revealed that plants use the same mechanisms to deal with different abiotic stresses. Flood and drought induce a large set of the same plant genes, including SUB1A. SUB1A gene enhances plant drought tolerance through reduction of leaf water loss (Fukao, Web). Therefore by using SUB1A, scientists can hit two birds with one stone.

In addition to flooding and drought, severe excessive salt stress is another threat for Bangladesh agricultural production. Nestled at a point where tidal waves from the Indian Ocean flow into the Bay of Bengal, 21 percent of land in Bangladesh has been intoxicated with excessive salt. Winds and currents cause saline water to mix with upstream rivers, and flooding and increased water levels further deteriorate the situation (Devnath, Web). The excessive salt causes plant leaf browning and stunted growth, which severely reduces the yield. Because plants have common genes that can deal with flood, drought and salinity, Bangladeshi scientists could first test whether SUB1A containing plants confer salt tolerance. If this is the case, SUB1A rice can solve all three major abiotic stress threats in Bangladesh. If SUB1A does not have a function in salt tolerance, plant scientists have been developing salt resistant rice varieties in other ways. For instance, Tomoko Abe and her colleagues mutagenized rice with heavy ions and screened for the salt resistant rice. Through multiple generation crossing, they have bred rice varieties with enhanced salt tolerance and yield production, which can be used for the Bangladesh rice breeding program (Nuclear-Power, Web).

The final challenge facing Bangladesh agricultural development is that individual Bangladeshi might not have enough money and transportation to get these new rice varieties. Thanks to many non-profit organizations and international institutions, they offer essential and vivid aids for the agricultural industries in developing countries. There are already a few programs that are working to provide aid in Bangladesh such as the World food Program and the ER Program (WFP, Web). An example of other organizations that could get involved is The Bill and Melinda Gates Foundation which aims to improve the wellbeing of humans through agricultural research. For example, it not only provides funding support for innovative fundamental agricultural research to develop crops with enhanced stress tolerance and yield production, but also promotes the accessibility of these resources to farmers from economic under-developed countries, including Bangladesh (Bill, Web).

The beautiful lands of Bangladesh are made poverty stricken by flood, drought and salinity. The main staple crop, rice, is frequently destroyed by devastating floods, which causes 63percent of farmers to lose their source of income. This also causes all of Bangladesh to be adversely affected due to the reduction in food supply, consequently deteriorating health. In order to solve these challenging issues, Bangladesh should partner up different research institutions and non-profit organizations to improve rice performance to different abiotic stresses and bring the seeds to the end users. SUB1A gene provides a promising genetic resource to breed rice varieties tolerant to water intoxication, drought and potential salinity. Bangladesh people should also actively participate in flood management. An integrative approach combining breeding tolerant varieties, shortening life cycle and flood management will prevent a great deal of rice yield loss. By controlling, adapting and avoiding floods and other abiotic stresses, Bangladesh will gradually grow to be a prosperous country. Food security will no longer be an issue, which will in turn dramatically increase human health in Bangladesh. Food security and human health build the solid cornerstones for a stable society; more people will have stable jobs, reasonable incomes and comfortable living conditions and people will send their children to schools for better education. By improving crops coupling with abiotic stresses, Bangladesh can be a well-fed, wealthy and healthy country.

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