RETHINKING THE SANDWICH: THE GLOBALIZATION OF WHEAT RUST[1]

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For the millions of north Indian wheat farmers, fate really does ride in the winds. A southern wind brings sighs of relief; they know that warm monsoon rains soon will revive their parched fields. But a western wind brings shudders of fear; all are unsure if that breeze carries with it a spore of the potent Ug99 fungus — the fungus that could single-handedly undermine the global food supply. Ten years ago, in the fields of Uganda and Kenya, a mutated strain of the Ug99 fungus, also known as wheat stem rust, successfully overcame the genetic defenses embedded in the local wheat plants, destroying entire harvests in the ground where they stood and releasing its spores into the air above them. Since then, the rust has followed the winds and the wheat north through Africa, Yemen, Iran and is now poised to strike the fields of North India and Pakistan — home to more than 20% of the planet's wheat supply and millions of the world's poorest, most vulnerable farmers. These farmers stand to swell the ranks of those farmers already devastated by rust in villages from Kenya to Iran. There, rust has successively destroyed up to 80% of the wheat crop.

In an attempt to avert catastrophe, the world's brightest minds have focused their attention on an advanced biotech lab in Minnesota to develop seeds resistant to the fungus. The long-term strategy for dealing with global crop pathogens such as wheat rust, however, actually may be found closer to Ethiopia, with one of the long overlooked orphan crops of the developing world. Wheat rust is not a new phenomenon. A rust epidemic in 1916 destroyed 100 million bushels in the US and Canada, and the last major North American episode (1954) destroyed 40% of the US wheat crop.

The fungus has plagued wheat crops and the human populations that depend on them for generations — the ancient Romans even worshiped Robigus, the god of rust. Each spring they held the Robigalia festival and offered sacrifices so that he might spare their wheat that year. For a time after the advent of the Green Revolution, all that was just becoming ancient history. In the 1970s, Norman Borlaug and other scientists of the CGIAR — the Consultative Group on International Agricultural Research, an internationally funded network of crop breeding and development centers — succeeded in suppressing the disease by promoting specific genes resistant to infection. As with Gregor Mendel and his peas (but on a mission to save millions), Borlaug and his colleagues used selective breeding to create high-yielding strains of wheat, choosing those that exhibited certain beneficial traits. With a little luck and a lot of hard work, they produced new strains of fast-growing, high-yielding and disease-resistant wheat. Such developments helped kick-start the Green Revolution. A generation of the world's farmers used these improved seeds, and wheat rust was fading into memory.

The Theory of Weary

The dark red lesions that infect the open stomata, or pores, of the wheat and siphon off the plant's nutrients have earned Ug99 many colorful nicknames — red rust, the red menace and the red death among them. But perhaps the real enemy of wheat farmers is what could be called the

[1] Miller-McCune Newsletter, Environment, July 26, 2010

Red Queen — after the fictional character from Alice in Wonderland who must run faster and faster on her accelerating treadmill just to remain in the same place. Like the Queen, farmers now have to spray more and more fungicide every year to keep the same yield as the year before.

Meanwhile, wheat researchers in the Minnesota biotech laboratory run by the U.S. Department of Agriculture frantically work to find a new genetic defense to protect against the mutated Ug99. As plant and fungus co-evolve, coached along unwittingly by humans, each contest intensifies, and the races never end. And ever since advances in biotechnology allowed humans to challenge bacteria, fungi and other microorganisms head on, we are now running into a lot of them.

In 1928, Alexander Fleming discovered penicillin, humanity's first antibiotic. It took more than a decade to refine the drug for distribution, but by 1944, the U.S. had 2.3 million doses ready to land with the Allied troops on Normandy beaches to combat the infections brought by German bullets and bayonets. Now we don't even trust penicillin to treat a moderate fever — the bacteria of the world have adapted and become almost completely immune to its effect.

Likewise in Omaha, Nebraska, the herbicide Roundup, widely used on U.S. maize, cotton and soybeans for decades, has lost part of its effectiveness as weeds adapted and now more easily survive its continued application. According to Walter Falcon, the deputy director for Stanford University's Program for Food Security and the Environment, and a former chairman of CGIAR's wheat and maize center in Mexico, "much of what happens these days [in agricultural research] is maintenance breeding — where pests come back and you have to battle them again after you thought the battle was over." Like Borlaug, Falcon was one of the journeymen of the Green Revolution. He lived in Pakistan while the revolution was in full swing and his work helped develop the South Asian wheat fields whose fate now hangs in the balance.

"Growing wheat is a roulette game," he says now, speaking from long experience. "We always know that rusts come and go — that is why you typically rotate varieties every eight or 10 years. But in humid tropical conditions [like East Africa], all bets are off." In warm, moist tropical regions, there is no winter frost to kill rust spores and annually reset the growth of that virulent fungal population. Furthermore, moist air improves the germination success of those spores and rusts tend to mutate more quickly in the warm weather. All together, the climate of East Africa acts like an incubator for the development of new mutations and new strains of dangerous plant disease. That is why even though Uganda and Kenya aren't global leaders in growing wheat, they have proven to be quite proficient at growing rust.

The Path Less Taken — Will it make the Difference?

In this through-the-looking-glass world of wheat rust and the Red Queen, a White Knight may emerge from the most surprising of places. Ethiopia, lying just north of the areas where Ug99 first began its march toward the wheat belts of India, was one of the first countries hit by the resurgent fungus. Surprisingly, it weathered the storm much better than any would have expected. One reason lies in Ethiopia's forgotten reservoirs of rust-resistant crops that can cushion the supply shocks created by threats like stem rust.

A particularly good cushion seems to be the soft, spongy and slightly sour injera dough. Injera is the bread served at any Ethiopian restaurant and used to sop up the lamb and lentils. It is made

from tef,[2] a grain native to that nation's highlands — almost exclusively grown in Ethiopia and largely ignored by the development scientists of the Green Revolution. Along with other crops that dominate the farms of many of the world's poorest nations, Ethiopia's native cultivars had never benefited from the extraordinary yield gains of Green Revolution varieties of wheat, rice and maize. Rather than developing native African crops, the big three that were developed for and had worked so well in Mexico and South Asia were merely transplanted to African soils. While the development of Ug99 points to the flaws in that traditional strategy, the overlooked, "orphan crops" in these areas are a big part of the solution to the current crisis. Over the past decade, Ethiopia — the name itself is synonymous with famine — has shown it can still teach the world a thing or two about food security.

Why Wheat?

Wheat did not even arrive in Kenya until 1904, when the British colonial government planted 480 hectares in pursuit of an export industry. In the 1970s, Kenya's post-independence government consolidated East Africa's wheat research laboratories and vigorously worked to attain the impractical goal of wheat self-sufficiency. In a sense, blame McDonald's for encouraging production — as people become richer, they often emulate media representations of how the West lives and dines. In large part, that means sandwiches — and sandwiches mean wheat. Plus, as the world urbanizes, people's jobs change, time becomes more valuable, and the time for food preparation is, in many cases, disappearing. Making a sandwich is simply faster than cooking a pot of rice, boiling cassava or rolling a mat of injera bread from tef.

Whatever the motivations behind growing wheat in East Africa, it has (through the spread of wheat rust) created a huge external cost for the world's food system – an externality that may soon be paid both by millions of Indian wheat farmers and the billions of consumers who could see wheat prices skyrocket in ensuing shortages. Falcon warns that it is within no one's pedigree to decide what crops a country should be allowed to grow. And beyond history's usual scapegoats for global ills — the British, McDonald's, globalization and urbanization — at least some of the blame lies with the agricultural development community itself. In the card game that is cultivating wheat in humid tropical climates, agricultural research since the 1970s has inadvertently stacked the deck.

Save our Orphans

Some 30 major food crops are currently or have historically been widely grown throughout the world. Since the Green Revolution, just the top three, maize, wheat and rice, have accumulated nearly 90% of the research and development funding. Those three crops have received most of the benefits of increased grain yields, increased fertilizer efficiency, faster growth periods and improved drought tolerance. With those immense advantages over the next 25 most important crops (which received little development funding), it is no wonder countries would want to import nonnative, climate-inappropriate, but technologically superior varieties for cultivation. Wheat rust was the inevitable result, and the scale of the physical famine nipping at its heels has

[2] Tef ***(Eragrostis tef)*** is a significant crop in only one country in the world — Ethiopia. The grain is especially popular in the western provinces, where it contributes about two-thirds of the protein to a typical diet. Most tef is made into *injera,* a flat, spongy, and slightly sour bread that looks like a giant bubbly pancake the size of a serving tray. People tear off pieces and use them to scoop up spicy stews that constitute the main meals. For the middle and upper classes it is the preferred staple; for the poor it is a luxury they generally cannot afford.

not been seen for so long that it is hard to imagine. Historically, the last large, wheat-dependent poor populations to see actual large-scale and annually repeated crop losses were those of France in 1789. Riots there didn't stop until a king and about 40,000 others ultimately lost their heads. In 2008, just the expectation of food shortage caused cereal prices to double and food riots to occur in cities from Mexico to Bangladesh.

Ethiopia and its orphan crops have not solved the world's hunger problem. On the contrary, poor baseline yields for Ethiopian cultivars — like tef — have resulted in chronic famine in much of that region. Nor are the Green Revolution research principles of improving yields and increasing disease resistance culpable. Ug99 did not occur because of human research; it occurred because there was not enough research on more agro-climactically appropriate crops. Perhaps the lesson, then, is that agricultural research should spend more time and money developing yield improvements for native, local crops such as tef, cassava, sorghum and pigeon pea so that developing countries will have viable alternatives to just wheat, rice and maize. With real alternatives to wheat, Kenya won't be under so much pressure to look like Kansas.

"A Very Nasty Tradeoff"

But few dollars are available to provide that choice. "Last time I looked, there were only four full-time yam breeders in the world. Who's going to do it?" asks Falcon. "The problem is twofold: First, overall agricultural investment is too low, and second, investment in developing countries has either stagnated or is decreasing." Total public agricultural investment hovers around $25 billion a year. A third of this investment goes toward the developing world, and only about 5 percent is allocated toward sub-Saharan Africa and its orphan crops. The publicly funded CGIAR system, historically the most effective and prolific development network for Third World agriculture, has an annual budget of $500 million. Those centers spend roughly $25 million directly improving the yield of orphans. Despite this historical disparity, or perhaps because of it, Falcon is optimistic that big gains can be made in the yields of orphan crops if only we give them a chance. "We've learned a lot from the big three that we can apply quickly to these new crops. There is a lot of low-hanging fruit, so to speak." If more funding were made available to these orphan crops, it is likely that large yield gains could be made quickly.

On the other hand, given the importance now of wheat, rice and maize to providing the world's raw calories (above 30%, and greater if including the amount used in animal feeds) — that reallocation decision is, according to Falcon, "a very nasty tradeoff." Perhaps though, the rapid and potentially catastrophic spread of wheat rust will force our hand in finally making that tradeoff. The lesson of wheat rust has been that **when we standardize our food system around a few staple crops, we also globalize our vulnerability to their pathogens**. We may be able to develop a new strain of rust resistant wheat and distribute it to India and Pakistan before the winds drop the first fateful spore onto those fields. If so, we will have breathlessly reached another checkpoint in that race with the Red Queen, earning a short respite as the clock resets.

But the race will go on indefinitely. In the world of agriculture, the future is always uncertain — success is only achieved with good weather and a lot of intelligent foresight. But one thing is sure: One way or the other, this round of wheat rust will beget orphans. If we do it right, and if the money is there, the newest batch of orphans in Ethiopia and Kenya, in India and Pakistan, will only be of the crop variety.