Asian Soybean Rust:
Simulated Economic and Environmental Impacts Nationally and the Southern U.S.

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Yield reductions and cost increases have been attributed to Asian soybean rust (ASR), a fungal disease caused by *Phakopsora pachyrhizi* H. Sydow and P. Sydow, in Africa, Asia, Australia, and South America. *P. pachyrhizi* (henceforth, ASR) is a virulent fungus that can infect over 95 species of plants, including soybeans, other cultivated plants such as peas and beans, and wild hosts such as kudzu, which is widespread in the United States and will likely aid the dispersion of the pathogen. ASR first was confirmed in nine states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, South Carolina, and Tennessee) in 2004. In this paper we examine the economic, environmental, and policy implications of ASR epidemics in the United States under three ASR –over–wintering scenarios in the southern U.S. and Caribbean basin.

Methods -- We estimated probabilities that ASR epidemics may occur in different U.S. soybean production regions based on estimated distributions of the pathogen in the southern United States and Caribbean basin during a mild, a moderate, and a harsh winter. This was done using the aerobiological model that was used by APHIS to predict extremely well the deposition of ASR spores in the southern United States that resulted from two November 2004 hurricane systems. A Bayesian approach was used to transform risk indices output by the aerobiological model into probabilities. In addition, historical time series on wheat stem rust epidemics was used to justify the aerobiological model's regional probability estimates.

Using Brazilian, state-level fixed-effects and time trends we estimate rust-free yields to compare to treated and untreated yields reported in fungicide efficacy studies conducted in Paraguay and Brazil during 2001–2003. According to the results, treated and untreated yields of soybean fields with ASR were an average 6.95% and 25.05% lower, respectively, than yields without ASR. These confidence intervals were combined with historical time series observations on minimum and maximum temperatures, rainfall, relative humidity, and soybean growing periods to estimate confidence intervals for regional treated and untreated yield impacts.

Using a fungicide return equation, $\pi = py(1 + i(f)) - cf$, where p was price per unit, y was rust-free yield per acre, c was material and application costs, f was fungicide treatments, and $i(f)$ mapped fungicide treatments into proportional yield impacts, and assuming no interaction between fungicides and productive inputs, producer demand for fungicides follows directly from the impact function. The impact function was estimated using two-stage least squares and – along with USDA baseline projections for real price and yield and material and application cost estimates from the fungicide registrants – yielded a bound for efficient cost impacts.

It is likely, however, that regions will treat ASR outbreaks differently depending upon their current treatment regimes. For example, soybean production in the Delta, where ASR is likely to over-winter, differs currently from other soybean-growing regions, in part due to the presence of fungal diseases that are endemic to the south. Because these diseases usually attack soybeans in the southern Delta on a recurring basis, most producers already treat soybeans with fungicides once or twice annually. One of the more commonly used fungicides (*Quadris*) by these Delta producers to control other diseases has been demonstrated to provide partial protection against ASR; the other provides no protection against ASR (*Tilt*).

How producers will adjust to ASR is unknown, but certain behavioral responses can be assumed. Because Delta producers currently treat soybeans for fungal diseases when present, most are likely to take a wait-and-see approach to applying fungicides for ASR and the other fungal diseases they might encounter. If signs of ASR are observed prior to any other fungal diseases, producers in the southern Delta may be inclined to use a product that works effectively on ASR *and* the other fungal diseases they historically have encountered on their operation. In this instance, producer may use one of the fungicides they have been using, or use another that is more effective against ASR but still effective against fungal diseases common to their operation. On the other hand, if symptoms of fungal diseases other than ASR are present early in the growing season (before first flowering), producers in the Delta may spray with a fungicide that is more effective on these diseases and not necessarily as effective in treating ASR, which may influence the spread of the disease. Only under limited conditions could one assume that producers will treat *only* for ASR, given the presence of other diseases in this region.

In the Delta, as in other regions, a producer's response to ASR, and any other fungal diseases present, will determine how variable costs of production change. Most producers in the Delta usually have one aerial application with one or two fungicides in the tank to address fungal diseases, therefore all scenarios would require only one additional application of fungicide(s). One additional aerial application of fungicides in the Delta costs producers approximately $3-6 per acre, depending on where the farm is located. The cost for additional fungicide to treat one acre ranges approximately from $8-13 per acre, depending on the product the producer uses. The cost for treating against *only* ASR, with two aerial applications and the associated fungicides, would range from $22-$37 per acre in the Delta; not much different from projected costs for treatment in the Corn Belt and other major soybean producing regions of the northern US. However, as most producers already treat their soybeans with some fungicide, and would likely require only one additional treatment to combat ASR, the marginal change in variable costs of production would be $13-20 per acre, depending on the fungicide applied.

Yield effects were difficult to project. It is estimated that yield losses from not treating soybeans in the Delta for fungal diseases other than ASR would be 5-7 bushels per acre. For Delta producers who currently to not treat soybeans for any fungal diseases, having to treat for ASR actually may result in yield increases of a few bushels per acre (5-7). However, for those producers currently applying fungicides to treat for other diseases, treating for ASR will not increase yields. On the contrary, soybean yields for these producers will remain constant, at best, and may decrease a few bushels per acre (3-5). Although yields may not decrease significantly with ASR, the decline may be sufficient to make soybean production uneconomical, given the historically low average yields in the Delta. We estimate that it will be difficult for producers averaging 30 or fewer bushels per acre to continue growing soybeans in the Delta.

Analysis -- We used a spatial-equilibrium, mathematical-programming model of the U.S. agriculture sector (U.S. Regional Agriculture Sector Model -- USMP) to simulate profit-maximizing adjustments made by crop, feed, livestock, and animal commodity producers and consumers under each over-wintering scenario. The over-wintering scenarios were simulated using the regional yield- and cost-impact confidence intervals; and expected economic and environmental impacts of ASR epidemics were examined, relative to USDA's 2010 baseline, using estimates of the probabilities that ASR epidemics occur by region under each scenario.

Results -- We found that soybean producers in the U.S. sustained losses of $623 to $1,422 million annually, depending on the scenario (no treat, treat or cure). Estimated losses were lowest ($623 million (15%) relative to baseline) when soybean producers do not treat for ASB. However, estimated losses to the entire U.S. crop and livestock sectors were lowest ($788 million (2%) relative to baseline) under the cure scenario.

In the southern U.S., soybean acreage was estimated to decline in the medium term in response to ASB under all there scenarios. Depending on the scenario, in the Southeastern U.S. soybean acreage was estimated to decline by 8 – 26%, while in the Delta, soybean acreage was estimated to decline by 2 – 20% by 2010. Change in pesticide use under the three scenarios ranged from -1% (no treat) to 13% (cure) in the Southeastern U.S. and -1% (no treat) to 16% (cure) in the Delta.