

Evaluating the economic impact of quality-reducing, seed-borne diseases: Lessons from Karnal bunt of wheat

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ABSTRACT

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Estimates of aggregate disease costs can be used for assigning research resources or to evaluate control measures. Most diseases cause production losses, but others affect quality and marketability. Seed-borne diseases also cause problems for the seed production and distribution industry. The aim in this paper is to examine issues relating to the economic impact of a quality-reducing, seed-borne disease, and to highlight differences compared to non-seed-borne diseases affecting yield only.

Economic evaluation of quality-reducing, seed-borne diseases needs to incorporate impacts of trading restrictions such as quarantines or embargoes imposed by purchasers. The costs of measures taken to control diseases also represent part of the economic impact of the disease. Full economic costs of a disease include the direct (yield and quality) costs and costs of the control measures. The costs of Karnal bunt of wheat in Mexico were found to include many control costs that have often been overlooked.

The optimal amount of resources to invest in controlling a disease depends on the likely annual costs of the disease and of control measures. Before implementing disease control policies, both the costs and the benefits of the policies need to be considered, taking the risks of each option into account, to ensure that the policy itself does not impose greater costs than the uncontrolled disease.

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ECONOMIC COSTS OF PLANT DISEASES

Agricultural production faces a continual threat from evolving or introduced pests and diseases, often causing substantial economic losses. The literature on disease losses is extensive (James, 1974; James and Teng, 1979; Teng 1985), as is that on economic strategies for farmers to control diseases (Carlson and Main, 1976; Teng and Gaunt, 1980; Reichelderfer, Carlson and Norton, 1984; Onstad and Rabbinge, 1985).

Less attention has been paid to estimates of the aggregate or regional costs of crop diseases (King, 1977; James and Teng, 1979; Brennan and Murray, 1989; Long 1989). Such estimates can serve two main purposes. First, losses for specific diseases can be a basis for assigning research resources to developing control measures such as disease resistance. Second, to efficiently allocate resources to regional control programs, estimated costs of preventative measures can be compared to potential losses if the disease becomes more severe or if it spreads to new areas (Carlson and Main, 1976).

Measures taken to control such diseases have an economic cost. The presumption is that the control measures, such as pesticide use or quarantine or regulatory restrictions imposed on the production and/or marketing of output, reduce the direct losses from the disease. Indeed, economically effective control measures are those that reduce the direct losses by more than their cost.

The yield loss caused by a disease can be measured from disease-yield loss assessment (James, 1974). The economic effects of a disease that causes yield losses can then be estimated by estimating supply with and without the disease and measuring the differences in economic surpluses. Under small country assumptions, this generally involves estimating lost production and valuing it at prevailing prices (for example, Brennan and Murray, 1989).

The economic impact of diseases that affect quality and marketability rather than output quantity is more difficult to identify and measure. Changes in output quality have been formulated as a shift in demand for the output (Unnevehr, 1986) or have been measured by the value of the price discount applied to the affected production (Brennan and Murray, 1989). Direct economic costs caused by a disease affecting quality include: (a) the value of quality losses; (b) the cost of handling and marketing infected product; and (c) the economic cost of the loss of markets through quarantine or marketing restrictions imposed following the presence of the disease. Control costs aimed at preventing the spread of the disease or reducing its severity include: (a) costs of in-crop control measures; (b) costs of quarantine or regulatory restrictions imposed on the production and/or

marketing of the crop; (c) regulatory costs associated with monitoring the disease; and (d) costs associated with extra processing or fumigation of the output from infected areas.

Analysis of the economic costs of seed-borne diseases involves additional consideration of the impacts on the seed production and distribution industry. Control costs associated with restrictions imposed on seed production and distribution in view of the risk of the disease spreading include: (a) losses incurred by seed producers because of minimum allowable infestations in certified seed; (b) extra costs incurred where seed has to be obtained from disease-free areas; and (c) extra costs of seed treatment because of the disease.

The aim in this paper is to examine the issues involved in determining the economic impact of a quality-reducing, seed-borne disease, and to highlight the additional issues involved compared to a disease affecting yield only. The findings of a study of Karnal bunt of wheat in Mexico are examined, and the implications are discussed. This paper is primarily concerned with measuring the total costs to a country, rather than with identifying the distribution of those costs between producers and consumers.

THE CASE OF KARNAL BUNT OF WHEAT IN MEXICO

One example of a seed-borne disease that affects output quality is Karnal bunt (*Tilletia indica*) of wheat (Warham, 1986). It first appeared in north-western Mexico in 1970, but caused little economic loss until the early 1980s when the level of infestation increased sharply in some years. Karnal bunt (KB) has been considered sufficiently important to warrant the imposition of planting and seed industry quarantines and restrictions since 1983. In this section, estimates are presented of the cost to Mexico of KB of wheat in north-western Mexico (Brennan and Warham, 1990).

Karnal bunt has only a relatively minor effect on yield, as generally only a small proportion of grains are infected. The average loss of yield in the KB areas of north-western Mexico (southern Sonora, Sinaloa and Baja California Sur) was estimated from data on the quantities of grain delivered with different levels of infected grain and by assuming a 25% loss of weight in infected grains. The average yield loss from KB was equivalent to 0.12% per year (Brennan and Warham, 1990).

Each load of wheat delivered to a receiving point in north-western Mexico has been tested for KB infection. Growers received a 1% price discount for each percent of infected grains up to 3.0%; loads with greater than 3.0% of infected grain were accepted as feed grain at a discount of 20% from the price for food wheat. The losses to Mexico rather than to the

farmers were taken as a 20% loss of value in heavily infected grain (> 3%), as grain with less than 3% infection could be used in processing without quality problems (Brennan and Warham, 1990).

Following the widespread KB infestation in 1982, wheat seed exports from Sonora (which had been exporting wheat seed to a number of countries for many years) fell sharply. Some countries imposed embargoes on seed imports from Mexico because of KB, and there have been no seed exports from southern Sonora since 1984. Continual changes in the world supply and demand for wheat seed make the estimated loss of seed exports from KB highly uncertain. Brennan and Warham (1990) estimated the average cost of the lost seed export sales from projected volumes (12 000 t per year) and current value added by seed exports.

Measures taken to reduce the severity of KB in the infected areas or to prevent its spread to other areas include quarantine restrictions on the crops planted in KB-infected areas and restrictions on the use of KB-infected seed. Quarantine restrictions on planting have been imposed on farmers' fields in southern Sonora since 1983–84. If delivered grain had more than 2% of infected grains the farmer was prevented from growing wheat on that land for the following three years, on the basis that the teliospores of KB can survive in the soil for several years. If the level of infected grains was 1–2%, the farmer could sow only durum wheat (which had greater tolerance for KB than bread wheat), while if the level was less than 1% there was no restriction. Farmers prevented from sowing bread wheat suffered a loss of income as it was more profitable than the alternatives. The total losses for farmers from the quarantine restrictions are estimated as the loss of income from producing durum wheat or other crops rather than bread wheat on the areas affected by the restrictions (Brennan and Warham, 1990).

Since KB can be spread by the use of infected seed, even crops with very low levels of infection have been rejected as unsuitable for certified seed. Losses incurred by seed producers when crops that have received extra inputs for seed production are rejected as unsuitable for seed because of KB were estimated from data on numbers of seed crops rejected because of KB. To ensure a supply of KB-free seed, seed production has also shifted away from the KB-infected areas in recent years to other areas, resulting in extra costs in transporting seed. Average transport costs were applied to quantities of seed transported. Although seed treatment is only partly effective against KB, seed produced in the infected areas of north-western Mexico since 1983 has been required to be treated with a particu-

t, metric tonne = 1000 kg.

TABLE 1
Estimated costs of KB in north-western Mexico

	Average annual economic cost	
	(\$US1000)	(% of total)
Direct costs		
– Yield loss	452	6.4
– Quality loss	2543	36.2
– Loss of wheat seed exports	1100	15.7
– Sub-total	4095	58.3
Control costs		
– Losses from planting restrictions	2011	28.6
– Costs for Sanidad Vegetal	192	2.7
– Rejection losses for seed growers	47	0.7
– Additional seed transport costs	615	8.8
– Additional seed treatment	63	0.9
– Sub-total	2927	41.7
Total costs to Mexico	7022	100.0

Source: Derived from Brennan and Warham (1990).

lar, more expensive, fungicide than would have been used in the absence of KB. The extra treatment costs were estimated for all local production.

Finally, additional costs have been incurred by Sanidad Vegetal, the Mexican plant quarantine authority, associated with sampling and testing for KB and with meetings held in relation to KB. Costs were extrapolated from detailed information on the costs actually incurred in one region.

The total costs of KB in north-western Mexico are estimated to average \$US7.02 million (in 1989 U.S. dollars) per year (Table 1), representing 2.0% of the value of the average crop of 1.93 million t in the infected areas. The major components of costs are the quality loss of infected crops (36.2% of total costs), the losses from planting restrictions (28.6%), the loss of wheat seed exports (15.7%), the additional costs of transporting seed (8.8%) and yield losses (6.4%). The direct yield and quality effects accounted for only 42.6% of the total costs.

DISCUSSION

The need to incorporate additional data and analysis in evaluations of quality-reducing, seed-borne diseases compared to diseases affecting only the quantity of output is demonstrated by the study of KB in Mexico. The economic costs were found to include many control costs that generally have been overlooked in the debate on policies for KB in Mexico. Since

direct yield and quality costs covered less than half the total costs, an economic evaluation of such a disease without accounting for the control costs is likely to understate, perhaps grossly, the economic importance of the disease. For example, estimates by Brennan and Murray (1989) of the potential economic cost of common bunt (*Tilletia laevis* or *Tilletia tritici*) in Australia are likely to understate the total costs of failure to control that disease. If the disease were widespread and uncontrolled by seed treatment, regulatory controls with similar far-reaching economic costs to those of KB in Mexico may well result.

In determining the policy response to a potentially threatening disease, "it is not sufficient to [show] that disease causes a loss; the magnitude of the loss must be...related to the gain obtained [from control]" (James, 1974, p. 27). The optimal amount of resources to invest in controlling a disease depends on: (a) the likely annual losses; (b) the costs of the control measures and (c) the effectiveness of the control measures in reducing average annual disease costs. Therefore, before implementing policies to control such a disease, both the costs and the benefits of the policies need to be evaluated.

It is apparent from the estimates for KB in Mexico that some control measures can be difficult to economically justify. For example, costs imposed by planting restrictions in southern Sonora are found to be greater than the benefits, measured as the reduction in yield and quality losses in comparison to Sinaloa (where there have been no such restrictions imposed) (Brennan and Warham, 1990). Therefore, *prima facie*, it appears that the costs imposed by the control measure may be higher than the direct costs prevented by the control although there are many other factors that can influence the incidence of KB in different regions.

In determining the appropriate policy response to such a disease, an important issue is the level of risk to be accepted in attempting to control it. A policy of 'no risk' in relation to the disease does not take into account the costs imposed by the policy itself in relation to the benefits from that policy. The appropriate strategy for countering a threatening disease is to assess the risk of disease spread under each of the options available and to compare the costs and net benefits of those options (Australian Government, 1988).

Another aspect to consider is the effect that the policies can have on costs and benefits of research programs. For example, restrictions on the movement of seed to reduce the risk of the spread of the disease could incur economic costs on the industry in the future by: (a) reducing the expected annual rate of yield progress from the breeding programs, (b) increasing the vulnerability to other diseases by slowing the rate of release of new varieties, and (c) delaying the development of KB-resistant varieties.

For Mexico, the costs imposed by this policy were estimated to be greater than the estimated likely losses from the spread of disease that the restrictions were designed to prevent (Brennan and Warham, 1990).

Large estimated aggregated economic losses from a disease indicates a need for adequate funds for research into both understanding the disease itself and possible methods of control. The results of the study into KB in Mexico also point out the need for research into the benefits and costs of various policy options.

In conclusion, the economic evaluation of seed-borne diseases that affect output quality and that are subject to quarantine restrictions involve many issues additional to those encountered in evaluating yield-reducing diseases. The costs of control measures, particularly those involving quarantine restrictions on farming operations or the movement of seed or output, need to be identified so that the merits of some of the policies can be evaluated in relation to their costs.

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REFERENCES

- Australian Government, 1988. Australian quarantine – Looking at the future: a government policy statement. Australian Government Publishing Service, Canberra, 55 pp.
- Brennan, J.P. and Murray, G.M., 1989. Australian wheat diseases: assessing their economic importance. *Agric. Sci.*, 2: 26–35.
- Brennan, J.P. and Warham, E.J., 1990. Economic losses from Karnal bunt of wheat in Mexico. CIMMYT Econ. Work. Pap. 90/02, CIMMYT, Mexico, D.F., 56 pp.
- Carlson, G.A. and Main, C.E., 1976. Economics of disease-loss management. *Annu. Rev. Phytopathol.*, 14: 381–403.
- James, W.C., 1974. Assessment of plant diseases and losses. *Annu. Rev. Phytopathol.*, 12: 27–48.
- James, W.C. and Teng, P.S., 1979. The quantification of production constraints associated with plant diseases. In: T.H. Coaker (Editor), *Applied Biology, IV*. Academic Press, London. pp. 201–267.
- King, J.E., 1977. The incidence and economic significance of diseases in cereals in England and Wales. In: *Proc. 1977 British Crop Protection Conference*, pp. 677–87.
- Long, D.L., 1989. Estimated losses from rust in 1988. USDA-ARS Cereal Rust Laboratory, University of Minnesota, St Paul, MN, 6 pp.
- Onstad, D.W. and Rabbinge, R., 1985. Dynamic programming and the computation of economic injury levels for crop disease control. *Agric. Syst.*, 18: 207–26.

- Reichelderfer, K.H., Carlson, G.A. and Norton, G.A., 1984. Economic guidelines for crop pest control, FAO Plant Prod. Prot. Pap. 58, Food and Agriculture Organization, Rome.
- Teng, P.S., 1985. Construction of predictive models: II. Forecasting crop losses. *Adv. Plant Pathol.*, 3: 179–206.
- Teng, P.S. and Gaunt, R.E., 1980. Modelling systems of disease and yield loss in cereals. *Agric. Syst.*, 6: 131–154.
- Unnevehr, L.J., 1986. Consumer demand for rice grain quality and returns to research for quality improvement in Southeast Asia. *Am. J. Agric. Econ.*, 68: 634–641.
- Warham, E.J., 1986. Karnal bunt disease of wheat: a literature review. *Trop. Pest Manage.*, 32: 229–242.