Costs and benefits of European Community (EC) measures against an invasive alien species- current and future impacts of *Diabrotica virgifera virgifera* in England & Wales

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ABSTRACT

In Europe, *Diabrotica virgifera virgifera*, the western corn rootworm, is an invasive alien species that has been spreading since it was first discovered in the former Yugoslavia in 1992. It was detected in England for the first time in 2003. A Monte Carlo simulation model was used to predict spread and determine the annual maize area at risk over ten years. An economic analysis of the costs and benefits of the EC risk management measures, designed to eradicate or at least inhibit the spread of this maize pest, demonstrated that in England & Wales, their strict implementation does not appear to be economically justified with management measures causing more losses than the potential damage caused by the beetle species itself. However, climate change scenarios indicate that raised summer temperatures will increase the area where maize can be grown and where *D. virgifera virgifera* can complete its life cycle, perhaps reaching more damaging population densities. Such a future scenario must be balanced with the impact of implementing strong action against this invasive alien species now.

INTRODUCTION

Diabrotica virgifera virgifera (Dvv), the western corn rootworm, is a univoltine oligophagous chrysomelid beetle from North America where it is one of the two most serious pests of continuous grain maize (Oerke *et al*., 1994). Larval root feeding is the primary cause of damage, reducing nutrient uptake and growth (Gavloski *et al*., 1992). In the USA, the combined cost of soil insecticides that target larvae, aerial sprays that target adults and crop losses approaches $1,000 million annually (Krysan & Miller, 1986). Dvv was originally detected in the former Yugoslavia in 1992 with severe damage first reported in 1996. In Serbia, yield losses can vary between 1% and 70% although mean losses are around 30% (Sivcev & Tomasev, 2002). To protect maize within the European Union (EU) against the spread of Dvv, it was added to the list of regulated pests in EC Plant Health legislation in January 1998 (Anon., 1998). Specific management measures for Dvv include delay of harvest, use of insecticides and the restriction of growing maize within 1km of an infested field for two years. Despite efforts to limit spread, by June 2003 Dvv had been detected in five of the then 15 EU countries (EPPO, 2004). To determine whether the pest had entered England, species-specific pheromone traps were placed in strategic positions identified as points of potential entry in June 2003. Dvv was subsequently detected for the first time on a pheromone trap in England in late August 2003 (Cannon *et al*., this volume). Following the finding, a cost: benefit analysis was conducted to assess the impact of implementing EC management measures that aimed to limit Dvv spread.

METHODS

In England, the vast majority of maize is grown for animal feed. The impact of Dvv and the EC measures used to manage Dvv will therefore be concentrated on livestock farmers. Two alternative scenarios were envisaged and, using a stochastic Monte Carlo simulation model, annual estimates of costs associated with each scenario were made over a ten-year period. The first model scenario estimated costs resulting from yield losses in continuous maize as a consequence of not implementing EC measures. To estimate the losses, the maize area at risk had first to be determined. A risk analysis for the UK shows that annual variation in climate dramatically varies the area suitable for Dvv establishment (MacLeod *et al.*, 2004). For example, in a cool year, sufficient heat is accumulated in only a small area to allow the development of a complete generation of Dvv. By identifying the regions where maize is grown and overlaying them with climatic areas suitable for Dvv development, the endangered area of maize can be determined (Table 1).

Table 1: The area of maize in England & Wales suitable for the development of *Diabrotica virgifera virgifera* under different climatic conditions (from MacLeod *et al.*, 2004)

	Climatic conditions		
	Cool	Typical	Warm
Maize area suitable for Dvv development (ha)	75	10,250	118,680

The model used the areas in Table 1 to define a triangular probability distribution of the minimum, most likely and maximum annual maize area suitable for Dvv development. Annual Dvv spread rates from the initial sites of infestation were selected from a triangular distribution, with parameters based on spread reported in the literature. For example, spread through the monoculture corn belt of the USA occurred at a rate of between 44 and 125 km/year whilst increased landscape diversity slowed spread to 33km/year (Onstad *et al.*, 2003). Baufeld and Enzian (2003) showed that without containment measures in place, spread of Dvv in Europe was 60 to 100km /year. Our model assumed that spread was a minimum of 60km, most likely 80km and maximum 100km, per year. The model combined the annual area suitable for Dvv establishment with the annual rate of spread and provided output in the form of maize area occupied by Dvv each year over the next ten years. From 10,000 model iterations, the mean annual area occupied was used to calculate potential future losses in yield.

Evidence from European countries suggests that there is a time lag of approximately five years between the first finding of Dvv and reports of economic damage in continuous maize (EPPO, 2003). Approximately 20% of maize in England & Wales is grown continuously and hence is potentially at risk from Dvv. The model assumed yield losses would occur in 20% of the area occupied five years earlier, representing the time lag for Dvv populations to grow and that losses would vary with a minimum of 10%; most likely 20% and maximum 30%.

The second model scenario estimated the costs to maize growers of implementing the EC measures. The model was used again to randomize the annual area suitable for Dvv establishment but used a slower rate of Dvv spread. In Europe, with containment measures in place, Dvv has spread at between 0 and 37 km per year (Baufeld & Enzian, 2003). Our model assumed Dvv spread was limited to between 0 (minimum) 20 (most likely) and 40 (maximum) km /year. To account for the time value of money, future impacts were discounted to show the present value of impacts.

Under existing regulations, once a field is found to be infested with Dvv, EC measures should be implemented in the field and all other surrounding maize fields within a 1km Focus Zone. Measures are also required in an outer Safety Zone, extending from 1 to 6 km from the infested field. Cannon *et al*. (this volume) describe the EC measures applied in the Focus and Safety Zones in England & Wales during 2003/4 in detail. Defra commissioned the farm consultants, ADAS, to conduct an economic analysis to examine the effect of the imposition of restricted cropping on livestock farmers growing maize. ADAS identified seven categories of maize-growing holdings and described how each may react to the imposition of statutory controls. Growers' response depended on many factors including farm type, size and location, the management system and any physical, technical and financial constraints. The ADAS study considered groups of farmers likely to respond in a similar manner and examined the effect of the rotational requirements on each group. In order to look at the likely cost to the whole industry, estimates of the numbers of growers and the area of maize grown was made for the most affected groups. Consideration was also given to the likely impacts of the CAP reforms and other industry influences. ADAS estimates were used in our stochastic model and we assumed all infested maize fields were treated with insecticide costing £23/ha per application. This cost was based on typical industry costs.

RESULTS

Costs of not implementing EC measures

Without implementing EC measures, on average, it would take three years for Dvv to spread before stabilizing to occupy over 39,000 ha of maize each year.Yield losses begin to be seen after five years. The present value of aggregate losses after ten years ranges from £1.9 million to £2.3 million (Table 2).

Costs of implementing EC measures

ADAS (2004) concluded that 90% of maize growers in England would be able to accommodate the rotational requirements without any significant additional costs but that livestock farmers currently growing continuous maize with severe constraints to change may incur additional costs averaging between £182/ha for fields in the Safety Zone and £243/ha for fields in the Focus Zone. Alternatives to growing maize considered by ADAS included growing grass, whole crop wheat or buying in maize from a contract grower. Income from growing a cash crop on the released land, which could alleviate the additional costs, was not included as the farm equipment and management or technical expertise may not always be available.

Table 2: Mean annual impact of Dvv on maize growers without implementing EC measures.

Year	Maize area infested (ha)	Continuous maize area suffering yield losses (ha)	Value of yield loss from (£'000)	Value of yield loss to (£'000)	Discount factor	Present value from (£'000)	Present value to (£'000)
1	18,645	0	-	-	1.0000	-	-
2	36,390	0	-	-	0.9662	-	-
3	39,555	0	-	-	0.9426	-	-
4	39,504	0	-	-	0.9021	-	-
5	39,553	0	-	-	0.8717	-	-
6	39,491	3,729	260	312	0.8423	219	263
7	39,324	7,278	508	609	0.8139	414	496
8	39,167	7,911	553	663	0.7865	435	522
9	39,531	7,901	551	660	0.7601	419	502
10	39,094	7,911	555	666	0.7345	408	489
						1,895	2,272

Over a ten year period of Dvv spread, during which almost 7,200ha will be holdings growing continuous maize with severe constraints to change, applying ADAS estimates of rotation costs plus costs of insecticide applications, to the mean of 10,000 model iterations, the impact of implementing EC measures on maize growers has a present value of approximately £14.7 million (Table 3). Under the statutory campaign, no yield losses are incurred since populations of Dvv are prevented from reaching economically damaging levels.

Table 3. The present value of economic impacts to maize growers having to spray against Dvv and those likely to have severe constraints in changing rotation from continuous maize.

Year	Maize occupied (ha)	Spray costs (£'000)	Maize severely affected (ha)	Rotation costs in severe area (£'000)	Discount factor	Present value indutry costs (£'000)
1	100	5	100	19	1.000	24
2	5,015	231	2,227	426	0.9662	643
3	8,936	411	3,712	710	0.9426	1,080
4	13,608	626	3,848	736	0.9021	1,290
5	17,912	824	4,483	857	0.8717	1,571
6	22,119	1,017	4,724	903	0.8423	1,778
7	24,590	1,131	5,030	961	0.8139	1,913
8	25,759	1,185	5,608	1,072	0.7865	2,028
9	26,411	1,215	6,158	1,177	0.7601	2,110
10	26,528	1,220	7,176	1,372	0.7345	2,228
						14,664

Cost: benefit analysis

Summing industry costs of implementing EC measures for the next 10 years, and comparing these with expected losses as a result of living with Dvv, the cost: benefit ratios range from 14.7: 1.9 to 14.7: 2.3, approximately 1: 0.13 to 1: 0.16, indicating that based on the assumptions used in the model, there does not appear to be an economic justification for implementing the measures against Dvv in England.

CONCLUSIONS

The stochastic model used to estimate the costs and benefits of implementing EC Dvv control measures in England & Wales shows that strict implementation of the measures does not appear to be economically justified over the next ten years. Management measures, especially the prohibition of growing maize in demarcated zones, can impose substantial costs on maize growers who have severe constraints to change. In contrast, with no statutory measures in place, yield losses caused by Dvv in continuous maize are likely to be significantly lower than the cost of measures resulting from forced rotation.

Costs resulting from a forced change in rotation are potentially substantial for some growers and whilst it is acknowledged that assessing the cost of a change in rotation is difficult (Baufeld, 2003) and thus not included amongst the costs of impacts considered by the EU *Diabrotica* project by Vidal (2003), not including such costs can seriously underestimate the impact of management measures on maize growers.

This analysis has assumed that the area of maize grown in England remains stable. With reform to the Common Agricultural Policy, low temperature tolerant maize varieties and increasingly warmer summers due to climate change, it is likely that the area of maize will increase. If so, the proportion of continuous maize would probably expand. Under the UK CIP02 climate change scenario, large areas of England will become suitable for Dvv by 2050 (Baker *et al*., 2003) and, with an increased maize area, this would increase the area of maize at risk and annual industry-wide yield losses from Dvv. Further work is necessary to assess whether the cost benefit ratio is likely to change sufficiently such that it would make economic sense to apply the EC measures now to avoid future losses under such a climate change scenario.

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