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Eradication versus manipulation: a case study involving *Avena fatua* in the Netherlands

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Summary

Control of *A. fatua* is mandatory in The Netherlands under the 'Wild Oat Control Order' which requires farmers to destroy plants, or at least the panicles, to prevent seed shedding. Prior to the introduction of this Order *A. fatua* was common. Infestations have now declined, and the weed is rare throughout the country. Following the discovery of a serious new infestation of *A. fatua* on the Statefarm in the IJsselmeerpolders, an eradication program was begun in 1982. This was essential both to comply with the Order and to preserve the value of this newly reclaimed land. After five years of treating infestations with selective herbicides and roguing, *A. fatua* continued to spread. New strategies consisting of a careful inventory of infested fields, preventive measures to avert new infestations and curative measures to control known infestations were implemented in 1987. The eradication program has cost approximately Hfl 6.0 million over 13 years with a peak of expenditure of Hfl 1 million in 1988. The area infested has been substantially reduced. The costs of the eradication program were 42% lower than those estimated for controlling *A. fatua* under a simulated policy of manipulation, which was based on the rate of spread recorded in the initial years of the program. Aspects of the eradication program that have contributed to its success are briefly discussed.

Introduction

Control of weeds in cropping systems usually aims to reduce their injurious impact on the crop, reduce spread and lower the population. These combined objectives can be regarded as a manipulative type of weed control policy. Such a policy implies that the weed will not be eliminated and that there will be recurring infestations and costs of implementing control.

An alternative control policy is to eradicate weeds by reducing the population (including propagules) to zero (Auld *et al.*, 1987). The benefit of eradicating a weed is freedom from losses and avoidance of continuing costs of control. Eradication programs are invariably highly labour and cost intensive because the cost of searching escalates as weeds become less frequent. Ideally, eradication programs should be justified by benefit cost analyses, but this is rarely the case because of data limitations. Consequently, most eradication programs are justified on social or political grounds, such as human health or drug policies, perceived threats such as noxious potential or ability to invade and denigrate environmentally sensitive habitats, valuable agricultural lands or by endangering productive enterprises or natural resources.

Twenty five years ago, *Avena fatua* L. was the most important weed of arable land in the Netherlands. Changes in crop rotation, improved chemical control measures and the gazetting of the phytosanitary "Wild Oat Control Order", a law instigated in 1965 at the request of farmers, led to a substantial reduction in the occurrence of *A. fatua* across fields and farms throughout the country (Naber, 1977). Under the Order, control of *A. fatua* plants and prevention of seed shed is mandatory, and the demise of *A. fatua* was especially attributed to the widespread adoption of these requirements by farmers.

During the early 1980's, new infestations of *A. fatua* were discovered in the IJsselmeerpolders in the Netherlands and a program of eradication was initiated (Naber *et al.*, 1992).

In this paper, the costs of the eradication program are reported and compared to those estimated for controlling *A. fatua* under a policy of manipulation, where intervention primarily involved annual tactical applications of herbicide.

Materials and Methods

The IJsselmeerpolders consists of newly reclaimed land. In 1980 approximately 20,000 ha of arable lands were placed under the jurisdiction of the Ministry of Public Works, as a Statefarm, for development as prime agricultural land. Once developed, land has been leased to private farmers, and by 1995 the area of the Statefarm had decreased to 4,000 ha. In 1996 the remaining land of the Statefarm is to be assigned to the local municipality.

In 1982, *A. fatua* was subjected to an eradication program on the Statefarm to comply with the Order, and ensure the high value of the land was preserved. The policy involved applying herbicides to control infestations and surveying, mapping and roguing fields.

Stricter procedures were enforced in 1987 as there had been considerable spread and an increase in density over the initial five years of the program. These new procedures entailed an inventory of all infested fields to determine the extent and distribution of infestations, the implementation of strict preventive measures to avert new infestations and tighter curative measures of chemical control and hand roguing with an emphasis on preventing seed shed.

Scouting teams inspected and rogued fields usually twice each year and infestations were mapped as light, medium or heavy, where:

Light means < 1 plant/20 m^2;

Medium means > 1 plant/20 m^2 to < 1 plant/m^2;

Heavy means > 1 plant/m^2.

Preventive measures consisted of using crop seed produced only on fields free of *A. fatua* and ensuring that machines used to work infested fields did not enter clean fields.

Curative measures were carried out with selective herbicides - in cereals, mainly difenzoquat during the first 10 years, then fenoxaprop-ethyl during 1993/4, and sethoxydim in beans and flax. On densely infested fields or patches the crop and *A. fatua* plants were totally removed and destroyed before seedset of the weed. Light infestations were hand rogued once or twice a year after the panicles became visible above the crop.

Since 1992, searching and hand roguing has been carried out from a tractor equipped with a 12 m boom with inspectors seated at each end. Operating at a speed of 6-8 km/hour along tramlines 24

m apart, and stopping only to remove detected plants, approximately 80 ha/day can be inspected and cleaned using Statefarm employees and student labour.

Administration of the program has involved the recording and mapping since 1982 of the infested areas, and the time and money spent in searching for and controlling the weed. These data are herein used to compare eradication versus manipulative type policies. Because the eradication program failed to contain the weed in the initial five years, when control relied primarily upon tactical use of herbicides, we have assumed that this period more closely resembled manipulation. The rate of spread calculated over the initial five year period was used to predict the area infested under a manipulative type policy, and this is compared wih what happened under the overall eradication program. In both schemes, yield loss arising from competition by *A. fatua* was calculated using the model of Cousens *et al.* (1986), where Y_{wf} = 7.5 t/ha, r_{max} = 0.01, γ = 0.01 and wheat valued @ Hfl 350/t.

Results

Under the eradication policy initiated in 1982, and reinforced with stricter procedures in 1987, the area sprayed increased from 38 ha in 1982 to 2660 ha in 1988, then progressively declined to 15 ha in 1993. In 1994 the area sprayed increased slightly to 66 ha (Table 1). These trends were reflected in the cost of spraying which totalled Hfl 2.86 million. A similar sum, Hfl 2.82 million was spent on searching and hand roguing, and this cost likewise peaked in 1987/88 and declined following the implementation of the stricter eradication procedures (Table 1). Loss calculated on a 1% yield loss (equivalent to 1 plant/m^2) over the area sprayed cost Hfl 0.36 million. The total cost of the eradication program over 13 years has been Hfl 6.04 million. Over this period, the area of the Statefarm progressively declined from 18,988 ha in 1982 to 6,520 ha in 1994.

Between 1982 and 1987 the spread of *A. fatua*, and subsequently the area sprayed, increased linearly (Fig. 1), indicating that the initial eradication measures were ineffective at containing the weed. Using the linear model, it was predicted that 5,406 ha would have been infested by 1994 if the weed had continued to be managed in the same way.

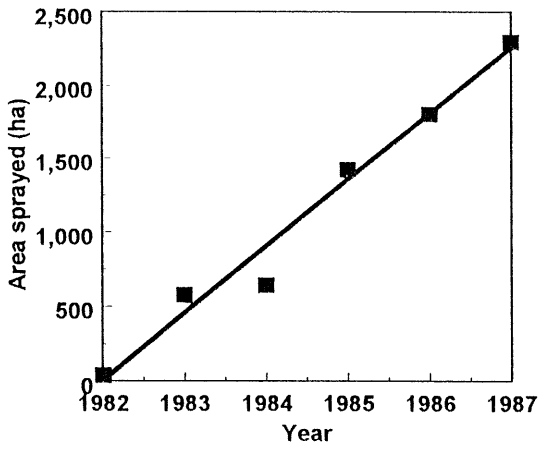

Fig. 1. Increase in area sprayed over initial five years of the *A. fatua* eradication program. Relationship $y = -446.9 + 450.2x$ ($r^2 = 0.975$).

Table 1. Actual cost of eradicating *A. fatua* compared with predicted cost of chemical control under a simulated policy of manipulation.

	Eradication program						Simulated manipulation		
Year	Actual area sprayed (ha)	Area of Statefarm (ha)	Average cost of spraying (Hfl/ha)	Cost of herbicide + application (Hfl)*	Cost of searching + roguing (Hfl)*	Cost of yield loss (Hfl)*	Predicted area sprayed (ha)	Cost of herbicide + application (Hfl)*	Cost of yield loss (Hfl)*
1982	38	18988	383.63	14578	89361	1183	3	600	103
1983	574	18307	199.47	114496	71250	17478	454	90559	13809
1984	640	17332	193.81	124041	183370	19125	905	175340	27005
1985	1422	15972	212.03	301504	370643	41888	1354	287089	39882
1986	1802	14758	235.29	424003	336046	53388	1804	424463	53450
1987	2296	13222	243.26	558528	536594	67633	2254	548308	66404
1988	2660	11960	234.07	622638	531030	77978	2705	633159	79282
1989	1559	11130	238.18	371330	276370	45127	3155	751458	91316
1990	529	10168	242.18	128111	180108	15012	3605	873059	102301
1991	693	9529	245.24	169949	65522	19096	4055	994448	111740
1992	70	8469	266.16	18631	45873	1873	4505	1199051	120566
1993	15	7638	157.19	2358	93915	394	4956	779034	130082
1994	66	6520	152.89	10091	37344	1733	5406	826523	141900
Total				2860258	2817426	361908		7583091	977840

*Values indexed to 1993 prices based on consumer price index data published in Landbouwcijfers 1995, Eds LEI-DLO/CBS.

Based on this predicted spread of *A. fatua*, treatment of the annually increasing area with herbicide was estimated to cost Hfl 7.58 million. As for the eradication program, an average of 1 plant/m^2 was assumed across the predicted area, which resulted in a total yield loss due to competition of Hfl 0.98 million. The combined cost under the simulated policy of manipulation was estimated at Hfl 8.56 million over the same period (Table 1).

Discussion

Over the term studied it appears that a policy of manipulation would have been 42% more costly than the actual cost of the eradication program (Hfl 8.58 versus 6.04 million). Under the eradication program the area infested with *A. fatua* has been significantly reversed and the annual maintenance cost has been reduced to < Hfl 50,000. The cost of the eradication program is underestimated since no account of the cost or value of destroying densely infested crops is included. On the other hand, the cost attributed to yield loss is overestimated by assuming an average density of 1 plant/m^2. By contrast, control by manipulation would have seen annual increases in the area infested and recurring annual costs of > Hfl 0.83 million. In addition, it is envisaged that losses from competition would also have increased, but until more information is available on the rate of increase in density this cannot be estimated. For these reasons we consider the benefit cost of this program is substantially underestimated.

Because elimination is generally considered uneconomic for established weeds, an eradication policy for a widespread weed such as *A. fatua* would be exceptional. This inevitability leads to the conclusion expressed by Zimdahl (1995) that such "Weeds will always be with us...". A common criterion for eradication programs, therefore, is that the weed has restricted distribution. In this case study, *A. fatua* in fact had restricted distribution. The Statefarm was essentially a closed system whereby there was control over imports to the area, eliminating any possibility of introducing new seed stocks of the weed. It was also managed under one policy, even though in the initial years it consisted of six sub-farms with individual managers. These circumstances allowed the whole farm to be managed without the need for a system of quarantine, as was necessary for example in the case of *Chondrilla juncea* L. in Australia (Dodd, 1987). This indicates that, given the desire, it would seem feasible to eradicate a weed in a regional context if all managers cooperated according to a common policy and the region could be isolated from external influences.

Eradication is most likely to succeed in practice if implemented soon after detection of a newly introduced weed in a country or region, before it becomes widely naturalised (Zamora *et al.*, 1989). This principle is evident, for example, in relation to *Cyperus esculentus* L. in the Netherlands (Naber & Rotteveel, 1986) and several weeds in Australia (Medd, 1987a,b; Dodd, 1990). Initiation of eradication procedures immediately after detection has undoubtedly contributed to the successful impact of the IJsselmeerpolders project, even though spread was not checked in the initial years.

Eradication is especially difficult in agricultural habitats because of the movement of seed between fields and farms by livestock or machinery, through dispersal in residues or by natural agents. Whilst searching and hand roguing were carried out in the initial years, in addition to spraying known infested fields, this failed to contain the weed in the IJsselmeerpolders project. Once steps were taken in 1987 to limit the dispersal of seed within and between fields and sub-farms the rate of increase rapidly declined, indicating that this was the critical factor governing containment. Although the manual operations were carefully and diligently performed, this indicates that seed must have been produced and dispersed. Thus, any measures which can be developed to improve the performance of searching and roguing would clearly be of benefit to eradication programs. The finding also indicates that, in the absence of effective dispersal mechanisms, some weeds could be tackled if they have vulnerable characteristics such as low rates of reproduction, poor recruitment or seedling survivorship or non persistent propagules.

An inability to form persistent seed banks could indicate that eradication is at least theoretically possible for certain species, if dispersal or seed production is controlled (Medd *et al.* 1995). This is the basis to an ongoing program to eradicate *C. juncea* in Western Australia (Dodd, 1987; 1990). Unlike the IJsselmeerpolders project, a further important aspect of the *C. juncea* program is that searching is undertaken on a voluntary basis by farmers who are implicated, keeping maintenance costs of eradication to a minimum.

In this case study, the population of *A. fatua* has not yet been eradicated ie. reduced to zero. As the area infested has declined it has become evident that some fields, apparently clean for two or more years, have been reinfested after deep ploughing or where disturbance from earthworks has been undertaken. In developing the IJsselmeerpolders, fields were deeply ploughed to encourage drainage and the mixing of soil to distribute salt concentrations. Inadvertently some seeds of *A. fatua* were buried in this process and a portion have apparently remained viable, providing a potential for reinfesting when brought to the surface. This menacing threat signals the need for ongoing vigilance, even in fields that have been apparently free of the weed for several years.

References

Auld B A, Menz K M, Tisdell C A. 1987. *Weed Control Economics,* London: Academic Press, 177 pp.

Cousens R, Doyle C J, Wilson B J, Cussans G W. 1986. Modelling the economics of controlling *Avena fatua* in winter wheat. *Pesticide Science* 17:1-12.

Dodd J. 1987. An analysis of spread of skeleton weed, *Chondrilla juncea* L. in Western Australia. *Proceedings 7th Australian Weeds Conference, Sydney, New South Wales,* pp. 286-289.

Dodd J. 1990. The role of ecological studies in assessing weed eradication programs. *Proceedings 9th Australian Weeds Conference, Adelaide, South Australia,* pp. 416-426.

Medd R W. 1987a. Impact of legislative actions on the invasion of *Carduus nutans. Proceedings 7th Australian Weeds Conference, Sydney, New South Wales,* pp. 290-293.

Medd R W. 1987b. *Carduus nutans* - ingression through indifference towards weeds. In *The Ecology of Exotic Animals and Plants. Some Australian Case Studies* pp. 222-239, Ed. R L Kitching, Brisbane: John Wiley & Sons.

Medd R W, Nicol H I, Cook A S. 1995. Seed kill and its role in weed management systems: a case study of seed production, seed banks and population growth of *Avena* species (WILD OATS). *Proceedings EWRS Symposium, Challenges for weed science in a changing Europe, Budapest,* pp. 627-632.

Naber H. 1977. Decline of wild oats in the Netherlands. *Proceedings EWRS Symposium, Methods of Weed Control and their Integration,* pp. 203-212.

Naber H, Rotteveel A J W. 1986. Legal measures concerning *Cyperus esculentus* in the Netherlands. *Med. Fac. Landbouww. Rijksuniv. Gent,* pp. 355-357.

Naber H, Medd R W, Meems J. 1992. Towards eradication of wild oats in the Netherlands. *Proceedings of the Fourth International Oat Conference, Adelaide, South Australia. Vol. II Wild Oats in World Agriculture,* pp. 91-93.

Zamora D L, Thill D C, Eplee R E. 1989. An eradication plan for plant invasions. *Weed Technology* 3:2-12.

Zimdahl R L. 1995. Introduction, In *Handbook of Weed Management Systems,* Ed. A E Smith. New York: M. Dekker. 741 pp.