Preface

Agriculture has entered a new phase. Since the 1940s the emphasis has been on producing as much food as possible. Although on a world scale there are still hungry mouths to feed, the western world is consuming significantly less food than is produced. To stem the production and cost to the exchequer, politicians in the USA and Europe have introduced set-aside schemes. The US is several years ahead of the EC and we can learn from their experiences. Farmers in the EC are today being faced with setting aside land on which they have formerly strived for higher levels of production and performance. This change of direction will lead to new challenges.

In the EC set-aside was first introduced in 1988 but uptake was low. However, in May 1992 EC Agriculture Ministers introduced a requirement for producers to set-aside land in order to be eligible for area aid. As a result large areas will be set-aside in the EC next year and in future years.

At present set-aside is largely seen in the EC as a means of supply control. Land may return to agricultural production on a rotational basis or at some future date to meet any increase in demand for food. Some land will inevitably never return to farming. In all cases we need to understand what effects on cropping and the environment will be.

Set-aside has been a feature of US agriculture since the 1930s and the area under set-aside was over 30 million hectares in some years during the 1980s. This was due to a number of reasons including income support, price stabilisation and soil erosion control. In both the USA and EC set-aside is now removing land from production but it has effects on the economics of farming, the social structure in rural communities, the environment and other crops in the rotation. This Symposium brings together information on all these aspects.

Within the EC many research projects have now completed 3–4 years work. Aspects covered include important work on the effect on soils, vegetation and fauna. These effects will often be immediately visible. The social and economic effects of set-aside are very important but may be less readily visible. A range of papers on these aspects are presented from many countries.

The wealth of information presented at this Symposium reflects a large part of what is currently available. As set-aside becomes a more important feature of the countryside, this data will be invaluable in guiding policy makers, farmers and advisers.

JAMES CLARKE

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ADAS
Atlas Interlates
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Monsanto Agricultural Group

ABBREVIATIONS

acid equivalent	a.e.
active ingredient	AI
boiling point	b.p.
British Standards Institution	BSI
centimetre(s)	cm
concentration × time product	ct
concentration required to kill 50% of test organisms	LC50
correlation coefficient	*r*
cultivar	cv.
cultivars	cvs.
day(s)	d
days after treatment	DAT
degrees Celsius (centigrade)	°C
dose required to kill 50% of test organisms	LD50
dry matter	d.m.
Edition	Edn
Editor	Ed.
Editors	Eds
emulsifiable concentrate	EC
freezing point	f.p.
gas chromatography–mass spectrometry	gcms
gas–liquid chromatography	glc
gram(s)	g
growth stage	GS
hectare(s)	ha
high performance (or pressure) liquid chromatography	hplc
hour	h
infrared	i.r.
International Standardisation Organisation	ISO
Kelvin	K
kilogram(s)	kg
least significant difference	LSD
litre(s)	Litre
litres per hectare	l/ha
mass	*m*
mass per mass	*m/m*
mass per volume	*m/V*
mass spectrometry	m.s.
maximum	max.
melting point	m.p.
metre(s)	m
milligram(s)	mg
millilitre(s)	ml
millimetre(s)	mm
minimum	min.
minute (time unit)	min
molar concentration	M
nuclear magnetic resonance	nmr
number average diameter	n.a.d.
number median diameter	n.m.d.
organic matter	o.m.
page	p.
pages	pp.
parts per million by volume	mg/l
parts per million by weight	mg/kg
pascal	Pa
percentage	%
post-emergence	post-em.
power take off	p.t.o.
pre-emergence	pre-em.
probability (statistical)	*P*
relative humidity	r.h.
revolutions per minute	rev./min
second (time unit)	s
standard error	SE
standard error of means	SEM
soluble powder	SP
species (singular)	sp.
species (plural)	spp.
square metre	m^2
subspecies	ssp.
surface mean diameter	s.m.d.
suspension concentrate	SC
temperature	temp.
thin-layer chromatography	tlc
tonne(s)	t
ultraviolet	u.v.
vapour pressure	v.p.
variety (wild plant use)	var.
volume	*V*
weight	*W*
weight by volume (mass by volume is more correct)	*W/V* (*m/V*)
weight by weight (mass by mass is more correct)	*W/W* (*m/m*)
wettable powder	WP

approximately		*c.*
less than		$<$
more than		$>$
not less than		$\nless$
not more than		$\ngtr$
Multiplying symbols—		Prefixes
mega	$(\times 10^{6})$	M
kilo	$(\times 10^{3})$	k
milli	$(\times 10^{-3})$	m
micro	$(\times 10^{-6})$	μ
nano	$(\times 10^{-9})$	n
pico	$(\times 10^{-12})$	p

1.
Political Aspects

Session Organiser and Chairman:
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SOME LESSONS ABOUT THE POLITICAL-ECONOMIC EFFECTS OF SET-ASIDE: THE UNITED STATES' EXPERIENCE

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ABSTRACT

The US has nearly 50 years of experience with set-aside programmes of varying size, structure, and operation. Several important lessons have emerged from that experience. Setting aside land distorts the US farm land market, resulting in higher land values, crop prices, farm income, and more intensive agriculture on remaining cropland. It also encourages conversion of extensive land to arable production. Targeting set-aside for environmental or other social goals lessens the social cost of land diversion. Lowering price or income support tied to land reduces the required compensation for set-aside. Land diversion programmes have not provided a long-term remedy to environmental problems. Set-aside contracts should be differentiated in form and length according to the nature of the environmental problem addressed. With the benefit of these lessons, EC policy makers can reduce the costs and enhance the potential benefits of set-aside.

INTRODUCTION

Setting aside profitable farm land seems a glaring mistake at first glance. Society is denied the food or fiber that would have been produced on the land. Increased production on other land (slippage) reduces supply control. The conservation benefits have often been questionable. Yet, the US has used some form of set-aside during 48 of the last 58 years. Set-aside reached near record levels of over 30 million hectares during 1983, 1987 and 1988, an area approaching 20 percent of US cropland or 40 percent of the European Community's arable land base.

The allegations about set-aside are numerous, and can be interpreted as favourable or negative depending upon your perspective:

1. controls production and supports prices
2. reduces government budget exposure for price and income support
3. supports or lifts farmland values
4. reduces consumer welfare from food and fiber due to higher prices or lower supplies
5. rests diverted land from production and provides some environmental benefits
6. can be used for production of alternative crops (e.g., biofuels)
7. encourages intensified management on other land in production because of higher prices and land values, and may induce conversion of extensive land to arable production; both forms of slippage will reduce supply control and may cause environmental harm.
8. reduces the economic base for communities with large amounts of diverted land

What forces compel set-aside decisions? What are the effects of set-aside, for the short-term and in the long-run? Who reaps the benefits and who pays the costs of set-aside? A search for the answers yields important insights, though there is not enough evidence to answer all questions convincingly.

The purpose of this paper is to distill the lessons about set-aside in the US setting for use in possible EC programmes. Before conducting the analysis, a brief description of current US set-aside programmes is presented. Then the discussion turns to the political-economic forces underlying set-aside, with emphasis given to the Conservation Reserve Program (CRP). Evidence on the performance of the CRP is reviewed to help EC policy makers avoid mistakes and strengthen potential programmes.

CROPLAND DIVERSION IN THE UNITED STATES

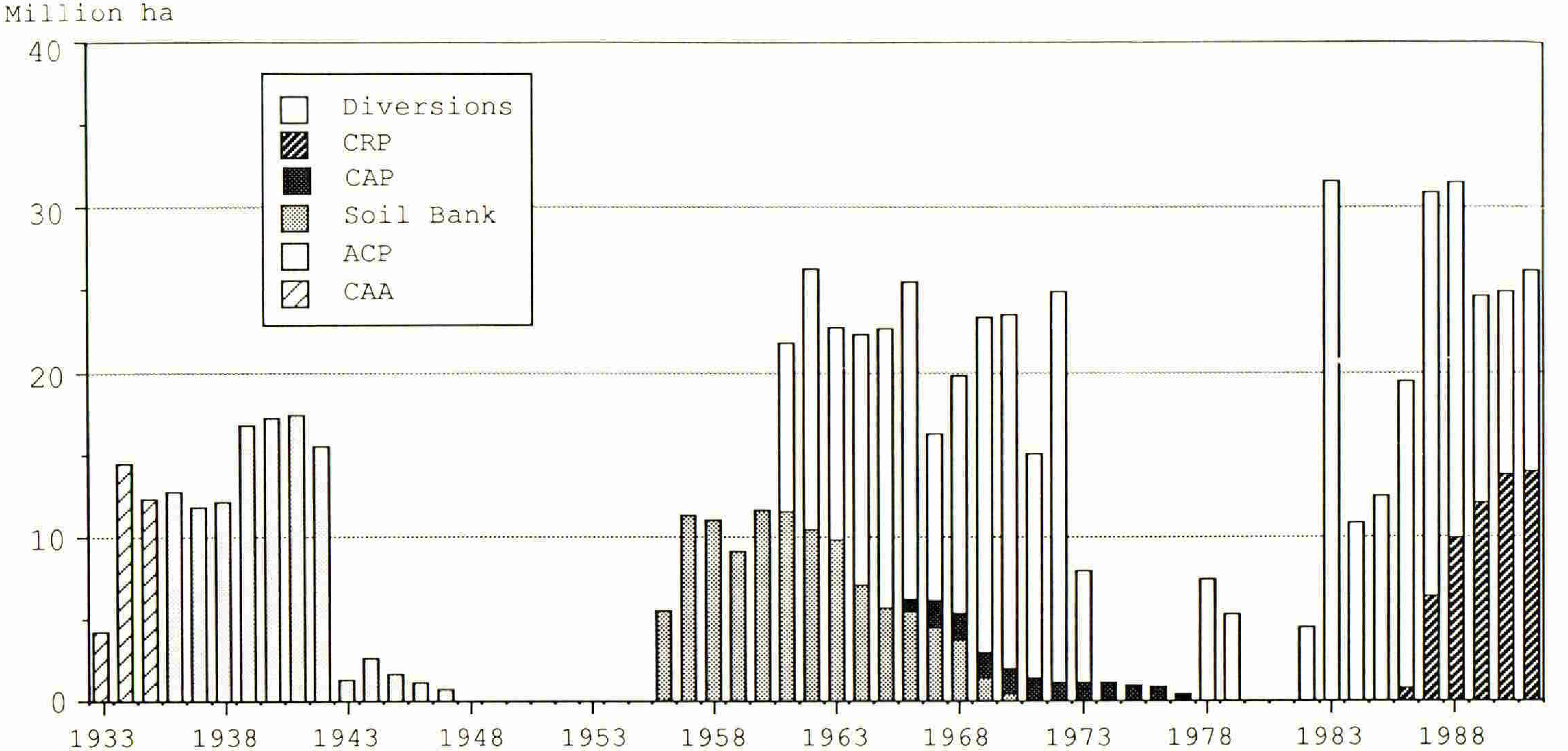
US farm policy since the 1930's has attempted predominantly to prevent unacceptably low farm incomes and stabilize prices through price and income supports. To avoid the accumulation of excess supplies from the supports, a variety of set-aside programmes have been implemented. They have ranged from required annual diversions for commodity price support participants to longer term approaches, such as the Soil Bank in the late 1950s and 1960s. Potter (1986) summarized the evolution of US cropland diversion programmes noting their direct and indirect relationships to environmental protection.

Current set-aside efforts are comprised of an Acreage Reduction Program (ARP) and a Conservation Reserve Program (CRP). They serve different purposes and thus vary over time according to need (see chart 1).

ACREAGE REDUCTION PROGRAM

The ARP is used to reduce production on commodity program base acres. It varies in size annually depending upon market conditions, increasing when carryover stocks are high and falling when stocks are low. For example, the ARP was reduced from 12 million to 7.5 million hectares from 1991 to 1992 because of low stocks. Note that the ARP level reached almost 25 million hectares in 1987 when stocks were high. Virtually all of the ARP set-aside is unpaid or required in return for receiving price and income support benefits by commodity program participants. Required rates vary year by year and by crops. There is a "paid diversion" option that is employed when excess supplies promise to be very costly to the government. The 1983 record diversion level resulted from the Payment-in-Kind Program which involved compensation. The compensatory set-aside option for supply control probably resembles most closely the EC set-aside proposals to date. Minimum conservation treatments are required while ARP land is set-aside, but environmental benefits are not a primary goal. Note that the ARP provides short-run flexibility in supply control, whereas the CRP is designed to divert land for longer periods. Therefore the CRP can not respond to short-term supply fluctuations, though the Secretary of Agriculture has authority to modify CRP contracts in cases of very tight supplies.

Chart 1. Cropland Acreage Reductions by Type of Program 1933-1991



CAA= Conservation Adjustment Act, 1933-1935; ACP= Agricultural Conservation Program, 1936-1947;
Soil Bank, 1956-1970; CAP= Cropland Adjustment Program, 1966-1977;
CRP= Conservation Reserve Program, 1986-current;
Diversions= Acreage Reduction Program (ARP) and other annual diversions, 1961-current

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Source: Crosswhite, W.; Sandretto, C. (1991) Trends in Resource Protection Policies in Agriculture. Agcultural Resources, Cropland, Water and Conservation Situation and Outlook Report; U.S. Department of Agriculture, Economic Research Service AR-23 Report, Washington, D.C., p. 44.

CONSERVATION RESERVE PROGRAM

During recent years, the other set-aside element, CRP, has been dominant (see chart 1). Authorized in the 1985 Farm Bill, the CRP was designed to achieve two dominant goals simultaneously; to decrease cropland soil erosion and reduce production capacity. Like the ARP, it depends on voluntary participation. Unlike the ARP, the CRP is explicitly intended to achieve conservation goals and contracts stand for 10 or more years. Osborn, et al. (1990) describe the program and its achievements from the 1985 Farm Bill through subsequent legislation prior to the 1990 Food, Agriculture, Conservation and Trade Act. Nearly 14 million hectares, or about 8 percent of US cropland, were enrolled during sign-up periods through July, 1989. Due to eligibility criteria and the permissible rental rate structure which favored the Great Plains, more than 62 percent of enrollment came from the northern plains, southern plains, or mountains regions where wind erosion predominates over water erosion. Total US cropland erosion has been estimated to fall 20 percent annually, or an average of 43 metric tons per hectare enrolled. The average annual rental rate over the 10 year contracts is $121 per hectare.

The 1990 Farm Bill retained the CRP but reoriented it toward specific environmental goals and redesigned programme rules to achieve greater cost effectiveness. Now known as the Environmental Conservation Acreage Reserve Programme (ECARP), it includes a wetland reserve element as well as the CRP dryland component. The 1990 act mandated that 16.2 - 18.2 million hectares be enrolled in ECARP by 1995, including the 13.7 million enrolled through 1989. Because the US Department of Agriculture (USDA) is reserving 405,000 hectares for wetlands, another 2.1 million hectares of other lands are necessary to reach the 16.2 million mandate. Eligibility criteria and enrollment procedures have been changed to emphasize water quality and other specific environmental problems, (see Ervin, et.al., 1992). Moreover, the maximum permissible rents have been revised to avoid paying more than market levels.

Another 700,000 hectares have been enrolled since March, 1991 with two important differences from previous patterns. There is a strong regional shift away from the Great Plains to the Corn Belt and Lake States, areas where water-caused erosion is perceived to cause more serious damages. Also, the average rental rate has risen to $141 per hectare for the new enrollments. If the environmental targeting procedures have been effective, however, the ECARP's environmental cost effectiveness may have improved.

THE POLITICAL ECONOMY OF SET-ASIDE

A conceptual examination of the beneficiaries and losers should reveal the driving forces of set-aside. In very simple terms, a set-aside programme will be approved if the benefits, as perceived by the legislators for their constituencies (and in return for their re-election votes), exceed the potential costs of passage.

Consider the possible CRP benefits and costs flowing to farmers, agribusiness, consumers, taxpayers, and other groups (Ervin and Dicks, 1988):

Benefits

1. Payments to participating landowners or renters
2. Production control leading to higher prices for non-participating producers and lower deficiency, storage, and export payments for government
3. Higher land values due to a reduced arable land base
4. Environmental benefits from reduced erosion and other conservation or pollution improvements
5. Increased profit for alternative commercial crops on set-aside land (e.g. timber)
6. Forage reserve to be used during emergency drought conditions if necessary

Costs

1. Less supply (and profit) for producers of crops normally grown on set-aside lands
2. Increased administrative costs for programme implementation
3. Higher prices for domestic and foreign consumers
4. Personal or community losses due to removing land from production
5. Increased environmental pressure on lands remaining in production due to higher crop prices (than would occur in an open market setting)
6. Reduced value of immobile excess capital and labor

The near-unanimous passage of the CRP in 1985 suggested that the perceived political benefits far outweighed the political costs. The twin advantages of reducing agricultural production capacity and controlling erosion were compelling reasons for approval. Lurking underneath public statements was the other obvious benefit; support for weak land values which were causing farm bankruptcy and bank failure. Agricultural producer groups benefitted broadly. Participating owners or renters received a compensatory payment for enrolling their land, which probably included any reduction in the value of immobile excess capital or labor. Crop prices were supported at levels above what otherwise would be possible, benefiting commodity programme participants and non-participants. Moreover, regular commercial agricultural use of the CRP land was not permitted, even if compatible with conservation goals (e.g., sowing and grazing of grass), thereby protecting other producers from increased supplies and lower prices (e.g., cattle farmers).[1] And, environmental interest groups received a big payoff to bolster their organizations.

Potential costs were compensated, were spread over larger and more diffuse groups than beneficiaries, or were perceived as small. Consumers would probably not perceive the incremental price bump in food costs.[2] Taxpayers were unlikely to notice the increased government revenue for land payments in an agricultural budget of nearly $30 billion. The loudest

[1] Emergency haying or grazing in specific drought areas has been allowed with decreased rental payments during three years. Also, fee hunting is permitted on CRP lands. The 1990 Farm Bill permits agricultural cropping between rows of trees (alley cropping) until the trees grow too large for harvesting.

[2] Any price increase due to the CRP hinges on the assumption that the newly diverted land would not have been accomplished through increased ARP set aside. Though there is surely some degree of substitution between CRP and ARP set aside, definitive evidence is not available.

protests came from businesses in local communities who perceived reduced farm supply, processing and storage business. To protect them from extreme hardship, counties were not allowed to enroll more than 25 percent of the county's cropland base. Despite the 25 percent limit, some communities reported very large negative economic effects, probably where the economic base was small and concentrated in agriculture.

Strong support for the CRP in a time of perceived high excess capacity and environmental problems from erosion was not surprising. Had the CRP not been approved, other supply reduction measures would have been necessary, such as increased ARP levels which are not without cost, especially if paid diversions were necessary. The farm community endorsed the CRP heartily because it restricted land availability, strengthened land prices, supported agricultural prices <u>and</u> paid the participating owners for their lost profits. Not a bad deal! Environmental groups got a large soil conservation programme that would not have been possible through normal funding channels.

The political economy of the CRP changed in 1990. Crop markets had tightened considerably, bolstering prices, incomes, and land values. The government deficit had skyrocketed. And much of the serious erosion-prone land had been enrolled or covered by conservation compliance. The result was a reorientation to other environmental problems with a firm limit on enrollment and more cost effective procedures (see Ervin, et al., 1992).

THE EFFECTS OF SET-ASIDE -- HAS THE CRP DELIVERED?

Implementation of the CRP determines the degree to which the benefits and costs match those expected in the political process. In effect, the outcomes determine the long-term political viability of the programme. Because the implementation procedures are rarely spelled out in authorizing legislation, it is important to evaluate actual versus expected performance.

Several major studies of the CRP have been conducted. The first, completed by the USDA's Economic Research Service, estimated major programme benefits and costs of a 18.2 million hectare version of the CRP authorized in 1985 legislation (Young and Osborn). To perform the analysis, investigators projected probable enrollment patterns based on early signup information. Estimated <u>net</u> benefits ranged from \$3.4 billion to \$11.0 billion in present value terms. [3] The net benefit figure is an approximation of the programme's economic benefits minus economic costs, such as the lost value of production. A large amount of the benefits were attributable to expanded wildlife habitat and surface water quality improvements. Net government expenses were estimated at \$2.0 billion to

[3] A pivotal assumption in this analysis of net economic effects is the extent to which new CRP enrollments substitute for ARP set-aside requirements. The USDA analysis assumed a low degree of substitution when, in fact, a much larger substitution appears evident from Chart 1. Had the larger substitution been permitted, the net economic benefits would not have changed a large amount. However, any government cost savings would have fallen considerably due to lower or zero price increases attributable to the CRP. Of course, this substitution problem between different forms of set aside does not exist in the European Community, at least for the moment.

$6.6 billion. Government outlays included CRP rental payments and conservation establishment expenses, minus direct and indirect savings in commodity programme payments. So, the programme's economic performance was expected to be very favourable based on early conditions.

But the assumed production, price and enrollment conditions did not materialize. Osborn and Konyar (1990) re-estimated the CRP effects in light of the actual 13.7 million hectare enrollment and the tighter commodity markets caused by the 1988 and 1989 drought conditions. Surprisingly, their results indicated again that net economic benefits were within the previous range (assuming full conservation plan implementation). Net government expenditures, however, were estimated to be considerably larger, because the higher commodity prices reduced the commodity programme savings estimated in the earlier analysis. So, the anticipated political economic effects were affirmed by these later estimates, with the exception of government costs, which were a key factor in the 1990 reorientation.

The USDA analyses presumed that the CRP would achieve the full conservation benefits under expected implementation guidelines. But the actual enrollment pattern and conservation conditions are likely to vary from expected outcomes. In a field study by the Soil and Water Conservation Society (SWCS), analysts found that not all CRP land had acceptable conservation practices one or more years after enrollment, mainly due to drought. (SWCS, 1992). More importantly, in many cases the initially reported erosion reductions due to CRP enrollment should have been lower than those used in the USDA evaluations. Therefore conservation and environmental benefits will be lower than projected and net benefits will fall. The degree of error was impossible to establish statistically.

The US General Accounting Office (1989) conducted a study which drew the general conclusion that CRP implementation had limited the achievement of conservation benefits and also incurred higher rental costs than necessary. More specifically, the pursuit of acreage enrollment and tree planting goals had restricted potential water quality benefits. Also, the maximum acceptable rental rates often exceeded local cash rental rates, sometimes by 100 to 200 percent. Again, these findings contributed to the pressures to reform the CRP in the next farm bill.

With these criticisms in hand, the CRP was reoriented in 1990 and 1991 through new implementation rules (Ervin, et al, 1992; Osborn, 1991). Though only two signups have occurred under the new rules, some early tendencies are clear. The proportion of enrolled lands is shifting from wind-erosion areas to higher value water-erosion problem areas. Average rental rates have increased somewhat, but probably do not exceed local cash rents due to new programme screening procedures. It is likely that programme cost effectiveness has improved as well.

WHAT HAVE WE LEARNED? -- LESSONS FOR THE EC

The precise structure and operation of the full EC set-aside programme is not clear at this point. However, there are several major lessons that emerge from US experience regardless of the ultimate form and implementation rules of the EC approach:

1. US set-aside for supply control (i.e., no commercial use) artificially distorts the land market, resulting in higher land values, crop prices, farm income and a more intensive agriculture on remaining cropland, and may encourage conversion of extensive land to arable production, assuming all other policy factors remain unchanged.

The potential for "slippage" from intensification and conversion of non-arable lands is worth special emphasis (Ervin, 1988). If farmers receive higher prices due to set-aside, and production quotas are not in effect, slippage will occur. The degree is uncertain. The intensive and extensive forms of slippage may also work against EC environmental goals of reducing agricultural chemical use in areas subject to water quality problems, and for protecting traditional extensive landscape values.

In a recent analysis, Abler and Shortle (1992) simulated the price, production and resource effects on EC agriculture of the MacSherry plan. Though their main analysis does not permit isolation of set-aside's effects alone, a separate simulation model suggested that the price and intensification effects (e.g., increased chemical use) should be expected. Because the EC policy reform package requires lower price floors and compensation for set-aside, the effects of set-aside in the EC are quite different from the US. Crop prices received by the farmers will fall (though farm income effects are uncertain due to offsetting compensation) and, ultimately, land rents and values will fall, as will labor quantities and wages due to a shrinking of the agricultural sector. Still, the basic lesson persists -- set-aside purely for supply control without commercial or conservation use is likely to lower society's economic welfare. In a second-best economic world resulting from government price and quantity interventions, set-aside provides another distortion, though sometimes a politically attractive distortion to the agricultural community.

2. Targeting the set-aside to achieve social environmental goals and/or other commercial use (e.g., alternative fuel production) lessens the economic cost of lower food and fiber supplies.

If set-aside is deemed politically necessary to contain government costs, then its negative effects can be reduced. Indeed, under certain circumstances, set-aside targeted to environmental needs may improve economic welfare under a government intervention policy requiring high supply control. The early CRP evaluations lend some credence to this proposition. Such a conclusion requires some precautions. First, set-aside programmes almost always experience substantial slippage due to offsetting actions by farmers, such as enrolling the least productive lands, farming new land, or intensifying production on other land due to financial constraints in the short-run or higher prices in the long-term. Second, the very act of targeting set-aside for other purposes may raise the producer's costs of production over untargeted set-aside, thus diminishing farm income. In such a case when very productive land is idled, requested compensation will rise. The US experience with the CRP suggests that targeted set-aside is more beneficial, especially with rudimentary prioritizing of environmental values and measures to control rental costs. In the EC, areas of water quality degradation due to agri-chemical use, of special wildlife or other biological value, and of high landscape aesthetic value may be appropriate targets.

3. Lowering price and income support lowers the required compensation for set-aside while also contributing to other environmental goals.

The EC policy reform package appears to incorporate this principle and should ease government and social expense. Simply put, lowering land profits due to price floor reductions decreases the necessary compensation for set-aside. And, lower prices lead to more extensive land use patterns with lower chemical use, etc. in the long run. Lowering price and income supports, however, also lowers the power to achieve environmental compliance measures, if they are deemed necessary.

4. Set-aside programmes are not a long-term environmental remedy.

Environmental problems arise due to incomplete or unenforced property rights systems. Set-aside programmes do not fix that problem. Even with elimination of agricultural programme support, such as in New Zealand, environmental problems have not been eliminated. Their ultimate solution may be delayed, but eventually the problems will resurface as set-aside contracts expire. The US experienced this phenomenon when 1960's Soil Bank land returned to production in the 1970's, only to be paid for again in the 1980's by the CRP. There should be a cheaper way to accomplish the desired conservation goals, such as permanent easements which restrict certain cropping practices but permit some long-term commercial use consistent with conservation or environmental goals.

5. Set-aside contracts should be differentiated in form and length according to the environmental problem.

The protection of a critical biological community from extinction, due to land use influences, requires a permanent instrument, such as a restrictive easement or covenant on the deed. Other problems, such as nitrate leaching due to cereals production, may require a shorter-life instrument, such as the CRP, if policy reform causes cereals to be unprofitable on the vulnerable land within the constraint period and thereby negates the need for long-run measures. A combination of contracts of varying lengths may also be desirable to permit some flexibility in responding to varying supply control conditions.

In summary, US set-aside measures have varied widely owing to different purposes and politics. The dominant current version, the CRP, has evolved because of the twin concerns of supply (and government cost) control and environmental problems. Revisions to the CRP under 1990 legislation and 1991 implementation rules may have brought closer the full environmental potential of set-aside. But, further improvements are possible. The EC's Environmentally Sensitive Areas programme is a small-scale model worthy of study for large-scale set-aside programme design. Potter et.al., (1991) outline the design and implementation of a possible conservation reserve in the United Kingdom to help adjust to CAP reform and restore conservation values to the countryside. With the luxury of learning from US experience, EC set-aside programmes should indeed be more effective and efficient.

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POLITICAL ASPECTS OF SET ASIDE AS A POLICY INSTRUMENT IN THE EUROPEAN COMMUNITY

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ABSTRACT

Set aside is a relatively recent policy innovation in the EC. It has evolved from a single multi-purpose scheme introduced in 1988 into a family of separate schemes serving different specific purposes of which the most important is supply control.

THE ORIGINS AND DEVELOPMENT OF SET ASIDE AS A POLICY INSTRUMENT IN THE EUROPEAN COMMUNITY.

There can be no doubt that the arable sector in the EC employs, economically speaking, excessive resources. Not only do our well-known surpluses show this up but also, by World standards, our arable sector is capital-intensive and labour-intensive as well in proportion to the area of land which is used. Land set-aside is therefore rather a surprising policy instrument to find in the EC, if it is seen simply as necessary withdrawal of a factor of production.

The appearance of set-aside in the EC arable policy is even more surprising when one considers that the basic design of the policy has been, and essentially still is, a price support policy. A policy instrument which means dealing directly with farmers, and which means making direct transfers to them from a budget, is a very profound innovation in such a context. To be able to explain how it came to be added into the price support policy, one has to suppose that set aside can achieve things which price pressure could not, or that something had gone very seriously wrong with price support and the arrival of new ideas like set aside and direct income aids were symptomatic of that fact. By 1986, it was indeed quite clear that, in the arable sector as in others price support was facing serious problems. Surplus stocks were accumulating very fast, and the increasing costs of managing and disposing of them were giving no marginal benefit to the farmers. The marginal income efficiency of Community expenditure had fallen to nothing.

Putting this into simple figures, late in the summer of 1986 one of the Member States pointed out that the cost of storing and disposing of an extra tonne of wheat was less than the average farmers profit from growing and selling it. The obvious solution, from the strictly budget-minded point of view, was therefore to pay the farmer not to grow those unwanted cereals. How different this is from the origins of American set-aside.

Because of the basic incongruity of set-aside in the EC context, this way of thinking took a long time to catch on. The purely budgetary merits of the original idea did not carry equal weight with all Member States; farmers organisations reacted strongly against an idea which they feared would undermine a public image of farming which was already on the wane; Members of the European Parliament found it particularly distasteful to pay farmers not to produce in Europe, whilst there was famine elsewhere in the world; and of course there was the nagging doubt as to whether or not the instrument would actually work: the budgetary cost of the psychological part of the incentive to join the scheme might be too high, and require premiums of such a level, that the cost-effectiveness of set-aside would fall away or even, if the dollar were to weaken or world markets recover, vanish altogether.

Despite this rather unpromising outlook, the idea of set-aside nevertheless made progress. If it were seen simply as a regionally-variable per hectare direct payment, it could of course be bent to suit a whole range of different objectives. For a Member State determined to preserve a price support policy, with high prices, an apparent step in the direction of supply control looked worth pursuing. One could talk of targets for the amount of land to be withdrawn. For others it was clearly better not to produce surpluses than to have to argue incessantly about the right way to dispose of them. Extremely important from the Commissions point of view was the realisation that the scheme at last offered an opportunity for overstretched farmers to get off the treadmill and quit the sector in conditions of some decency, thus improving the prospects of being able to pursue a more market-oriented price policy, the social costs of which were being ever more acutely felt by the Agriculture ministers.

So finally, in february 1988 the scheme was approved by the Heads of State and Government meeting in Brussels. It still took several months to gain wider approval but by the harvest of 1989 land which would otherwise have grown cereals finally lay fallow. The set-aside scheme in force by then had sprouted, in addition to its budgetary logic, socio-structural, environmental, and even non-agricultural objectives, and they were all rolled into one. It was to be used as a support framework for diversification, afforestation, extensive grazing, support for growing lentils and chickpeas, for wildlife cover, and more. Such a wide range of purposes for an idea which had grown from a simple costing exercise on a tonne of surplus cereals, was to be its undoing.

Certainly the most outstanding example of set-aside being adapted to serve a specialist interest was the suggestion that set-aside land should not lie fallow at all, but be used to grow cereals instead. This looks like going round in circles, but the thought, very popular in some quarters, was that the variable per-hectare premiums could be used to try and help finance new non-food uses of cereals. With some premium in his pocket, maybe a cereals farmer could be persuaded to sell his grain so cheaply that a new use for them could be contemplated. Since this use would never have been profitable with cereals priced at the normal protected level, it could be considered as an additional market outlet. Therefore, at least one of the basic aims of the scheme, to help control overproduction relative to market outlets, would not have been compromised.

It has to be said that this non-food scheme as it was called, was not a success. Only just over 100 hectares were entered in the first year, and those involved decided not to repeat the experience. The important lesson drawn was that, for all its advantages as a direct aid scheme, voluntary set-aside was a poor vehicle for launching a new manufacturing activity. From an industrial client's point of view, a patchwork of piecemeal suppliers whose interest might evaporate at the first change in policy, was hardly worth looking into, let alone a basis for making an investment in new processing capacity.

With so many different assigned objectives, set-aside was not apparently making a great success of any of them. The EC Court of Auditors pointed out that even the hoped-for budgetary cost-effectiveness of the scheme had been a delusion partly because of the unexpectedly high administrative costs involved. And, with less than 2 million hectares withdrawn by 1992, it clearly was not meeting with overwhelming interest from farmers.

With the agreement this summer of the Community's agricultural policy reforms, it was high time for a rethink. The most important objective now is clearly that of reducing production whilst the arable sector comes to terms with more realistic prices. The socio-structural and environmental objectives are not forgotten but are to be dealt with separately and can at last have tailor-made regimes specifically designed to achieve each of them. So now we shall have two types of set-aside, one for the purpose of supply management and another, in fact a series of others, specifically designed for socio-structural, forestry, and environmental purposes.

To avoid falling between two stools again, the Commission has steadfastly refused to allow the production control version to be turned into a hybrid with an environmental premium scheme. A particular example of this is the Commission's resistance to fixed set-aside as opposed to rotating set-aside for supply control purposes. Fixed set aside may well give the greater potential wildlife benefits, albeit usually not in the best places to actually realise them, but it is also, in the Commission's opinion, likely to give a much higher "slippage" factor on inhomogeneous farms because of the natural tendency of farmers not to set aside their best fields first. In addition, it would after all be a pity to lose such environmental benefits as had been gained whenever, at the mercy of the World cereals trade, the set-aside percentage is reduced, or even set at zero as has recently been decided in the United States.

The new production control version of set-aside will still have, however, an appendage inherited from its parent, which is that non-food production will be allowed upon it. Maybe this time something good will come of that; three intelligent ideas that we have noted so far are to use the area as space in which to try genetically engineered crops for their ability to spread in the environment, or to plant the land with nematicide radishes to clean it before growing something else, or to grow a cover crop with a good capacity for absorbing animal waste and which subsequently burns well and, most importantly, at a profit. In all likelihood, people's ingenuity will continue to give us surprising new ideas as to how best to make use of this newly available space, and the prospect of the vast majority of the bigger and better-managed farms being involved is less likely to discourage industrial and research interest.

THE INFLUENCE OF BASIC POLICY CHOICES AND "SUBSIDIARITY" ON THE DETAILED ADMINISTRATION OF SET ASIDE FOR SUPPLY CONTROL

From the point of view of the administrator, there are three things which are constantly in mind when contemplating set aside as a supply control measure: the scheme has to achieve its objectives at a reasonable cost; it has to be simple yet be applied evenly throughout the EC; and it has to be designed with a view to minimising abuse of the rules.

In looking at the supply control set-aside regime that we have from this winter onwards these preoccupations can be dealt with in turn.

A brief look at our cereals sector, which produces about 180 million tonnes a year against a domestic demand for them of barely 140 million tonnes, would suggest as a first approximation that set-aside should have an objective of removing over 20 % of all cereals area from production, if one could assume a rather low slippage rate. But given the fact that cereals prices in the EC are to be reduced by 29 % by 1995, and that therefore some extensification of production is likely; that some of our cereals can be exported profitably; and that they will regain some share of the animal feed market by being priced competitively at last, a lower objective might well suffice to bring the market back into some semblance of a balance. Although making any forecasts for so far ahead is bound to be extremely imprecise, it looks as though some 5 to 6 million hectares of set aside would be necessary, on condition, of course, that the land withdrawn is not replaced by new land entering the sector, a problem that will be returned to later.

As it turns out, an objective like that could quite feasibly be reached by a set-aside rate of 15 % on the relatively small number of farms in Europe which have more than about 20 hectares of arable land each. This formula has a certain political attractiveness about it because of the configuration of farming in Europe, where the vast majority of farms are very small indeed, and are percieved as having gained relatively little benefit from price support policy, whilst the minority of larger farms are percieved to have benefitted heartily, even excessively, from it and can be asked to bear the brunt of this supply control measure. That is what the Commission proposed in the summer of 1991.

Much to the delight of Commission administrators, the USDA forecast what they thought the result of these proposals would be, within days of their appearance. By using quite different methods, the USDA reckoned that the Community cereals crop would go down by some 17 million tonnes, almost exactly the Commission's own figure.

What, then, would be a reasonable cost for the set aside of 15 % of the arable land on those middle to large size farms ? It could be anything from zero, which could be the case if the new compensatory payments for farm income support were made conditional upon set-aside, and it could range up to a nearly two billion Ecu a year with a "full" rate of compensation, which would cover, as with the previous voluntary set aside, the opportunity cost of not growing cereals. The Commission decided to steer between these two extremes, and proposed to pay for only a limited amount of set aside on each farm. This idea of concentrating the payments on the relatively small farms was an unashamedly political choice and it became known as modulation. Within the CAP it has parallels such as limits on headage payments and limits on the size of piggeries that are eligible for investment aid, and in principle at least it is similar to the American limits on crop programme payments to individual farms. It nevertheless greatly incensed some European farm ministers. In the final stage of the negotiations of the farm policy reform package, the Portuguese presidency decided to suggest doing away with it, and to pay as much or more for set aside land as for land growing crops. This was a very expensive decision but no doubt a politically expedient one as well.

In this way the administration's first question, as to how to reach the target at acceptable cost, was answered by a political fait accompli.

The second aspect for the administrator is the worrying one of how to keep the scheme simple on the one hand yet precise enough to be sure that it can and will be applied evenly throughout the Community.

To help in the design of the precise prescriptions the Community at any rate does have one year's worth of experience with a temporary voluntary set aside scheme which was introduced in 1991. Nearly a million hectares were put into this scheme whose purpose was to reduce the size of the 1992 harvest so that the Community would not have to embark upon a reform whilst carrying the added burden of bulging surplus stores. The experience with that scheme shows that one needs to be precise about three things, and it must be said that we would not necessarily have been able to guess what they were in advance. They are the rules on the length of the fallow period, the rules as to where an eligible fallow may be put, and the rules about how the obligations under the scheme should be transferred between one farmer and another. The question of what other activities are allowed on the land, which might have been thought to pose no end of problems, was actually very simply settled by saying that nothing "lucrative" was allowed in view of the very high level of benefits on offer. In exceptional cases and especially when non-lucrative uses were envisaged, a test which is applied is to ask whether or not the intended activity would have been compatible with growing an arable crop. For example, motor cycle races on the land throughout the year obviously would not do, but in August they might, because the land in any case would probably have been free at that time. Such a rule is good in Community legislation, because it is a model of simplicity that can be applied even handedly by any administration. It avoids making a long and bureaucratic list of prescriptions which can never cater for all circumstances and which, while seeming broadly reasonable, can lead to absurd results in the unforeseen ones. The same rule of thumb will be used for the new supply control set aside scheme.

To come now to the rules about the length of the fallow period, one which is too short at the beginning, or starts late in the year if it can be put that way, will give farmers a good opportunity to spot which of their crops is most poorly, so that that one can be ploughed in to create the fallow. This raises the slippage rate for the scheme significantly. Equally, a fallow which is too short at the end, or stops too soon, becomes a welcome opportunity to start work sooner on making a good job of the cultivations for a following crop, such as early planted colza. This not only means that the long-term cost-effectiveness of the scheme is lower, but also that there may be an artificial movement into early-sown crop types to follow set aside, quite irrespective of what a market would indicate. Considering this experience with the one-year set aside scheme, it was noted that a careful rule would probably be desirable with a repeated and rotating set aside. Such a set aside would need to be able to follow a crop of beets or maincrop potatoes, for example, so an early start to the fallow period would pose problems for the farmer. On the other hand, a fallow period which continues right up until July would add little or nothing to the merits of the scheme in some regions of the Community. As a result the Member states have been given a considerable degree of flexibility in setting the rules that are most appropriate in their respective territories, given the types of crops which are grown there and the the timing of their growth cycles.

Next was the question of where a farmer may put his fallow. In the temporary, generous, and voluntary scheme, it was specified where the fallow was to be found. Now, with the less generous and quasi-obligatory set aside scheme, it is sufficient simply to say where we do not want to find it. The first example would be on land which has only recently been ploughed up: in such a case one can doubt whether the land was really suitable for growing arable crops, or else it would probably have already been ploughed up some time ago. If set aside is offered on such land, one would suspect a high rate of slippage, and it may even be that this fallow is a net addition to the arable land of the holding, so that the set aside on that farm made no real contribution to controlling production at all. In this context it has been noted with some dismay that despite paying dearly for the set aside of nearly 2 million hectares of arable land, the area which is down to cereals in Europe has fallen by only 1.1 million hectares since 1988. For these reasons the rules about where the fallow may be placed are limited to those which are necessary to be sure that the land set aside had actually already formed part of a normal arable rotation on the same farm, but will be firmly enforced.

Precision about the responsability for the set aside obligations turned out to be very important in Europe because of the frequency with which plots of land pass from the management of one farm to that of another. It has been estimated that in Germany, not even counting the 5 new Länder, there are something like 70,000 such exchanges every year; in Ireland, much arable land is managed under conigre leases of no more than 11 months; in Mediterranean areas, it can be somewhat difficult to uncover at all who exactly it is that is managing a particular plot of land. With one-year set aside it was possible to solve many of the questions raised by this with a simple fiction: that for the purposes of the scheme it could be assumed that the farm as constituted at the time of the request for participation, remained. Using this idea as a guide, it was easy to work out what should happen when farms combined or separated. Again, this is a simple rule of thumb which, used as guidance by all of the Member states' administrations, will see to it that there is an even-handed application of the scheme.

The third aspect of great importance to the administrator is that the set aside scheme should not be liable to abuse. To be sure that a scheme is not heavily abused one needs to combine a deterrent sanction for abuse with a high probability, from the potential abuser's point of view, of being found out. For EC schemes, a powerful combination of sanction and risk of discovery is obviously very necessary because of the importance of money involved. The main sanction for misbehaviour with regard to Community farm income supports tends however to be just the recovery of aid unduly paid, plus interest. This is one of the reasons why the Commission is now concentrating hard on raising the probability that a doubtful claim will be spotted. An ideal way to do this is to use satellites to look at what the farmers are doing and, equally important, to let the farmers know that satellite imagery is so used and that archives of past images are available. The knowledge that these archives of satellite images exist, which can show what a farmer was doing with each of his fields in a given year, according to expert opinion and according to farmers themselves, is perceived as a major risk factor by the potential fraudster.

Prevention, as always, is far better than cure and if abuse can be prevented in this way, it considerably reduces the burden on Member states' administrations of having to distinguish between deliberate abuse and honest mistakes. To the extent that any subjectivity creeps into those distinctions, there will be a risk of differences of treatment between farmers in different Member states, which is wholly contrary to basic Community policy. So although the use of satellite imagery may give the appearance of a step in the direction of a "big brother" attitude, it is also an honest attempt to use dissuasive techniques precisely as a means of reducing the need for policing and litigation. In reviewing these concerns felt in Brussels, it can be seen that devices are sought which simplify the scheme for administrations, that seek fairness of treatment for farmers, and that give value for money.

SET ASIDE FOR PURPOSES OTHER THAN SUPPLY CONTROL.

The Community has now adopted three other land diversion schemes besides the set aside scheme for controlling arable production. They are collectively described as the "accompanying measures" to the reform package and they cater for three preoccupations: To help the Member states with prepension schemes for farmers and farm workers who need to leave the sector; to promote the use of farmed land for forestry, recreational, and similar non-agricultural purposes; and to pay for new environmental services provided by farmers.

Presented as such the accompanying measures are much less obviously set aside schemes in the familiar sense. This goes to underline the problem noted earlier, that a single five-year set-aside scheme may not be the best solution for objectives so diverse as controlling arable production and for improving wildlife habitat.

It is clear that for schemes such as these to function well they need the benefit of local knowledge in their design. Therefore, a decision about a great deal of the content of these schemes is delegated to the Member states. To start with the prepension scheme, although it is quite in order for the Community to expect the released land not to simply be switched from the arable to some other surplus producing agricultural sector by the neighbours or other organisations who take it over, the manner in which the rules about the departing farmers' pre-pension interdigitate with national social security systems is naturally something to be left to the Member states. Equally, when it comes to the aid for afforestation, local knowledge is bound to be useful in deciding what needs to be done, and what not done. Thus, the Member states must see to it that afforestation plans are defined at the most appropriate level. This was not necessarily the case with the afforestation option under the previous multiannual set aside scheme, and hopefully will contribute to its greater success. In these two measures, then, it can be seen that much local input is expected to be built in, which draws on the knowledge and experience available in the Member states as much as possible.

The third of the accompanying measures introduces a considerable innovation. It may be used for several different purposes, but which all have the same underlying philosophy which is that benefits for the rural environment can be bought. The purposes cited include, for example, the relief of grazing pressure on fragile or poor pasture, the provision of habitat for rare or endangered species, the management of unproductive land in a way that reduces fire risk, and for the information and training of farmers in environmentally friendly practices.

An important premise for payments under this measure is that the farmer should be providing a service which is additional to what his normal code of good agricultural practice would lead him or her to provide as a matter of course. This is to reduce the moral hazard problem, whereby the public purse may find itself paying for something which the farmer was already going to do anyway, or even for not doing something which he or she in reality only had the vaguest intentions of even contemplating. This is why the Member states are required to specify what positive services they require from farmers under these headings in programmes which will set out the areas concerned, the objectives to be attained, and the specific means for achieving them, which may incidentally go so far as to require a farmer to make the necessary undertakings in respect of the the whole of the area under his or her management and not just for a small part of the holding.

The Community's intention, then, in the design of these accompanying measures, and just as in the case of using set aside for supply control, is to fit the measures as precisely as possible to the specific objective being sought. In both cases, the better the fit, the greater the chances that the objectives will be reached, an important principle of policy design.

2.
Crop and Soil Relationships

Session Organiser and Chairman: KEITH GOULDING
Session Organiser: EDWARD BACON

CHANGES IN SOIL MINERAL NITROGEN DURING SET-ASIDE AND EFFECT OF ROTATIONAL FALLOWS ON THE YIELD AND N-OPTIMA OF SUBSEQUENT CEREAL CROPS

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ABSTRACT

The effect of both one-year and permanent set-aside on soil mineral nitrogen (SMN), was studied at five sites in England. In the experiment comparing one-year set-aside, ground covers permitted under the UK government's 'Set-aside' scheme were compared with cultivated fallow and continuous cereals. Areas set-aside in one season were then cropped with winter cereals for two seasons at a range of nitrogen fertiliser rates. Amounts of SMN were less in spring than in the previous autumn and were highest after cultivated fallow and least after ryegrass. There was a yield benefit from all set-aside treatments when compared with continuous cereals. Yield benefits were greatest in the first season after set-aside for most covers. Optimum nitrogen rates for cereals after set-aside were similar to those required by cereals after cereals. In the second experiment, comparing land managed under the terms of the permanent set-aside scheme, initial results from SMN monitoring have shown small differences between treatments.

INTRODUCTION

Surplus production of cereal grains within the European Community (EC) and the increasing cost of storing grain sold into intervention, led to the introduction of a 'set-aside' scheme throughout the EC in 1988. In an effort to reduce surpluses, farmers were offered financial payments to take land out of production (Anon, 1990). Under the terms of the scheme various alternative land use options were permitted, including rotational and permanent set-aside. Under rotational set-aside, individual fields are fallowed for a single season after which they are returned to cropping, whilst under permanent set-aside the individual field is fallowed for five years.

The introduction of the set-aside scheme has raised several issues regarding its possible effects on the environment. One aim of the UK government is to reduce nitrate leaching from agricultural systems, therefore, it is important that rules for the management of set-aside do not increase the potential for nitrate leaching. For farmers, a major issue is the rate of payment relative to the cost of managing set-aside and the effects of the fallow period on the financial performance of following crops. In addition to these issues, public concerns demand that set-aside should be managed to be both visually attractive and to offer enhanced wildlife habitats wherever possible.

In order to answer some of the technical questions on the management of land entered into both rotational and permanent set-aside, experiments were established at five sites in England in autumn 1987 (rotational) and 1989 (permanent).

MATERIALS AND METHODS

Rotational set-aside experiment series

This experiment series was sited at five ADAS Reseach Centres. The sites were, ADAS Bridgets Hants., ADAS Boxworth Cambs., ADAS Drayton Warks., ADAS Gleadthorpe Notts. and ADAS High Mowthorpe Yorks. At each site three-year experiments were started in the autumns of 1987, 1988 and 1989.

In the first season, a range of set-aside treatments were established. These compared, with continuous cereals, bare fallow, Italian ryegrass (*Lolium multiflorum*), forage rape (*Brassica napus*), herbicide fallow, natural regeneration and spring sown legumes; only selected treatments were included in all experiments. There were four replications of each main plot treatment. Each main plot was 21-24m wide and 24m long.

Soil from each treatment main plot was sampled to a depth of 90cm (30cm at High Mowthorpe) during the autumn, spring and summer of the set-aside period and in the autumn and early spring of the succeeding first wheat crop after the set-aside year. Soil cores were analysed for soil mineral nitrogen (Patton & Crouch, 1977).

In the second and third years of each experiment, all plots were sown with winter cereals. In the first wheat crop sown after the set-aside, a range of nitrogen fertiliser rates, 0, 80, 120, 160, 200, 240 and 280 kg/ha N were applied to sub-plots, each 3-3.5m wide and 24m long. At all sites, crops were managed in accordance with normal farming practice regarding choice of cultivars, P and K fertiliser and agrochemical input. Grain yield and percent dry matter (%d.m.) were measured at harvest for each sub-plot.

Soil mineral nitrogen and yield were analysed for each site using analysis of variance. The N-optimum in the first wheat crop after each set-aside treatment was estimated using a linear plus exponential curve fitting model (3:1 grain:nitrogen price ratio).

Permanent set-aside experiment

Experiments were established in the autumn of 1989 (1990 at Gleadthorpe) at the same five sites selected for the rotational set-aside experiment. The performance of a standard arable rotation (AR) was compared with perennial ryegrass (RG) (*Lolium perenne*), perennial ryegrass and white clover (C) (*Trifolium repens*) mixture, natural regeneration (NR) and perennial ryegrass receiving a low rate of applied nitrogen. Some set-aside plots were cut during the season with mowings left in situ and on others mowings were removed. Full details of all set-aside treatments and management have been reported by Clarke & Cooper (1992). There were four replications of each set-aside treatment. Individual plots were 12m wide and 24m long. Soil was sampled to a depth of 90cm (30cm at High Mowthorpe) on selected set-aside treatments; in the autumn or winter after the soil had returned to field capacity and in the spring when leaching had finished. Soil cores were analysed for soil mineral nitrogen.

RESULTS

Soil mineral nitrogen

Rotational set-aside experiment

Previous site history, rainfall and set-aside treatment affected SMN. There were large differences between sites, SMN being greatest on the heavy soils at Drayton and lowest on the sandy soils at Gleadthorpe. Overall, the amount of SMN at Bridgets (silty-clay loam over chalk) and Boxworth (silty-clay) was intermediate to that recorded at Drayton and Gleadthorpe. Rainfall between sampling dates had a large effect on the decline in SMN over the winter period, the largest reductions being associated with the greatest rainfall.

Amongst the set-aside treatments, bare fallow and perennial ryegrass represented the extremes in terms of effect on SMN (Table 1). Differences between set-aside treatments during the first autumn and winter were small and generally not significant. Treatment differences increased during that year, SMN increasing where bare fallowing was practised and decreasing with perennial ryegrass relative to the standard continuous cereal treatment.

The greatest differences between set-aside treatments were recorded at the August set-aside year and November test year sampling dates. Results presented in Table 1 show the relative effect of set-aside treatments on SMN at the November test year sampling date. Italian ryegrass consistently reduced SMN at all sites, bare fallowing consistently increased it, whilst natural regeneration and spring-sown legumes were variable in their effect.

TABLE 1. SMN 0-90cm depth (0-30cm at H.Mowthorpe) for set-aside treatments, expressed as a percentage of that recorded for continuous cereals, at the November test year sampling date. Mean of three seasons at each site.

Site	SED	Bare fallow	Italian ryegrass	Natural regen.	Spring legume	Continuous cereal
		SMN as a % of continuous cereals				(kg/ha N)
Bridgets	13.1	123	62	105	99	117
Boxworth	11.1	185	66	106	-	114
Drayton	13.1	147	60	122	120	149
Gleadthorpe	11.1	207	60	138	115	71
H.Mowthorpe	13.1	142	65	91	138	6
All sites	10.5	161	63	112	118	

Permanent set-aside experiment

Differences in SMN between set-aside treatments during the first year of the experiment were small (Table 2). The greatest differences were between the control arable rotation, which received standard nitrogen inputs, and the other sown set-aside treatments. A comparison of the three mowing treatments on the clay soils at Boxworth and Drayton suggests that SMN was marginally less for the perennial ryegrass and ryegrass/clover treatments compared with natural regeneration. Comparison of the two ryegrass/clover treatments where mowings were left in situ or removed, suggests that SMN was reduced slightly where mowings were removed, but overall these effects were small.

TABLE 2. Amounts of N (kg/ha) in soil at Bridgets, Boxworth and Drayton, for selected set-aside treatments.

Site	NR	RG	RG/C	RG/C	Low N RG	Normal AR	SED
	Cut, mowings left in situ			Mowings removed			
Bridgets							
Winter 89-90	178	195	215	196	176	296	
Spring 90	125	85	106	97	213	178	
Autumn 90	53	46	48	52	53	126	
Spring 91	66	64	81	98	65	86	
mean	105	98	113	111	127	171	10.7
Boxworth							
Winter 89-90	63	61	44	49	56	64	
Spring 90	59	53	45	42	50	84	
Autumn 90	77	55	61	51	52	78	
Spring 91	101	55	48	31	46	91	
mean	75	56	50	43	51	79	4.1
Drayton							
Winter 89-90	80	63	68	67	68	79	
Spring 90	94	90	95	77	148	304	
Autumn 90	136	89	82	78	96	145	
Spring 91	190	112	141	105	134	134	
mean	125	89	96	82	112	169	11.9
All sites	102	81	86	79	97	140	5.5

Grain yield and optimum rate of nitrogen

Rotational set-aside experiment

The effect of set-aside treatment in the absence of applied nitrogen on the yield of wheat in the first test wheat crop is shown in Table 3.

TABLE 3. Yield of wheat in first test year for zero N sub-plots, expressed as % difference of continuous cereals. Mean of three seasons at each site, except spring legume (two seasons).

Site	SED	Bare fallow	Italian ryegrass	Natural regen.	Spring legume	Continuous cereal
		Yield as % of continuous cereals				(t/ha)
Bridgets	13.7	+48	+29	+42	+61	2.07
Boxworth	11.4	+6	-18	-4	-	5.87
Drayton	13.7	+24	+6	+29	+42	5.04
Gleadthorpe	13.7	+44	+11	+19	+17	2.18
H.Mowthorpe	13.7	+85	+29	+65	+79	2.96
All sites	6.9	+41	+11	+30	+50	-

Similar patterns were reported at most sites, bare fallow and spring sown legumes giving the largest response and ryegrass the smallest, relative to the continuous cereals. Percentage responses were smaller on the clay soils, but yields at zero applied nitrogen were greater. At only one site, Boxworth, did set-aside give yields less than those of continuous cereals. At Boxworth, most problems followed ryegrass due to poor seedbed conditions and slugs. The apparent high yield benefit to wheat after set-aside at High Mowthorpe was due to very low yields for continuous cereals in one season.

Mean optimum nitrogen rates were similar for all set-aside treatments, but there was a wide range reflecting differences in soil type and yield potential. Overall, mean optimum nitrogen rates, at 170-184 kg/ha were similar to Index 0 after cereals (Anon, 1989).

A comparison of wheat yields for each set-aside treatment at 200 kg/ha N, in the first test year and at standard commercial N rates in test year two (winter barley at Gleadthorpe), is shown in Table 4.

TABLE 4. Grain yield expressed as % difference of continuous cereal, at 200 kg/ha N in test year 1 and at standard N in test year 2. Means of 3 seasons except test year 2 (mean of 2 seasons) and spring legumes (2 years test year 1, 1 year test year 2).

Site	SED	Bare fallow	Italian ryegrass	Natural regen.	Spring legume	Continuous cereal
		Yield as % of continuous cereals				(t/ha)
Bridgets	3.78	+8.3	+12.0	+8.1	+6.2	6.77
Boxworth	3.41	+4.7	0.0	+2.4	-	8.08
Drayton	3.78	+6.5	+5.9	+14.7	+12.4	6.44
Gleadthorpe	3.78	+16.3	+7.1	+10.1	-2.3	5.69
H.Mowthorpe	3.78	+22.8	+8.6	+26.6	+27.2	7.36
All Sites	1.89	+11.7	+6.7	+12.4	+10.9	6.87

Over all sites, there was a yield benefit from all set-aside treatments compared with continuous cereals and benefits were greater in the first cereal than in the second. Ryegrass and bare fallow showed a greater benefit to the second wheat at Boxworth.

DISCUSSION

In the rotational set-aside experiment, bare fallowing and Italian ryegrass treatments represented the maximum contrast in terms of soil cover. Bare fallowing resulted in most SMN, a consequence of mineralisation of organic-N in the soil organic matter and from plant residues, whilst Italian ryegrass gave the lowest values, presumably because of the uptake of nitrogen into roots and above-ground dry matter.

The increase in SMN during the set-aside year for bare fallow, and the contrasting effect of the ryegrass cover in minimising the amount of readily leachable N both during and after set-aside, appears to justify the decision not to allow bare fallow.

Whilst the permanent set-aside experiment is still in its early stages, preliminary results suggest that SMN may be marginally less for the sown ryegrass and ryegrass/clover covers than for natural regeneration. This may be a consequence of a more even and rapid establishment of the sown cover compared with natural regeneration.

Overall, the inclusion of clover within the sown seeds mixture appears so far to have had little effect on SMN. However, at Bridgets where there has been vigorous growth of clover, SMN has been consistently a little higher at most sampling dates for the grass/clover than for ryegrass.

Wheat yields from first test wheat crops in the rotational set-aside experiment at zero applied N, give an indication of soil nitrogen supply and the effect of individual treatments. However, these differences were overshadowed at optimum N levels, and at commercial rates of nitrogen fertiliser application, yield benefits from the set-aside compared with that from continuous cereals, were small. In practice, the benefit from the set-aside was no smaller than would have been expected from traditional break crops in arable rotations.

ACKNOWLEDGEMENTS

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EFFECT OF SET-ASIDE ON SOIL NITROGEN AND SUBSEQUENT CROPPING

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ABSTRACT

A long-term field experiment was established to assess the effect of different green covers in permanent set-aside land on the leaching of nitrate-N, and on the residual soil nitrogen and its effect on the requirement for nitrogen fertiliser in subsequent crops. In order to allow for year-to-year environmental variation on the establishment of the green cover, its maintenance and in the response of the following crops to nitrogen fertiliser, the trial was laid down over a period of three years with two replicates being established in autumn 1989, 1990 and 1991.

Compared with the annual loss of 22 kg/ha of nitrate-N from agricultural land in NE of Scotland, the Set-aside Scheme would appear to offer the potential to reduce leaching of nitrate where a dense green cover with a high content of ryegrass is established. By contrast a clover-rich sward might result in an increase in loss of nitrate from agricultural land.

INTRODUCTION

It has been reported that 22 kg/ha of nitrate-N are lost from agricultural land in the NE of Scotland and differences in concentrations of river nitrate-N were suggested to be related to differences in use of the agricultural land (Edwards *et al.*, 1990). However, data were not available for specific land uses. The first objective of the present investigation was to monitor soil nitrate in land taken out of cereal production and managed under the Set-aside Scheme. However, the choice of cover crop for Set-aside could be vital if the leaching of nitrate-N is to be minimised.

Previous cropping effects the net annual flux of mineralised nitrogen and the amount of soil nitrogen available to the next crop (Scholefield *et al.*, 1991). The choice of cover crop is thus expected to play a major role in determining the level of residual soil nitrogen and the benefit to subsequent crops after a period of set-aside. The second objective of this study was to assess the effect of different green covers on the residual soil nitrogen and its effect on the requirement for nitrogen fertiliser in subsequent crops.

MATERIALS AND METHODS

Site

A field experiment was established at the Scottish Agricultural College farm at Tillycorthie (grid reference NJ 918232), 10 miles to the north of Aberdeen. The soil is a poorly draining till of the Pitmedden Soil Series and is derived from mixed acid and basic igneous rocks (Glentworth & Muir, 1963). A sandy loam top soil extends to a depth of about 30 cm with a clear change into a sandy clay loam. The field had been continuously cropped with winter barley for a number of years.

Treatments

Six treatments were chosen following the harvest of winter barley in August 1989. They comprised three permanent set-aside treatments, one rotational set-aside treatment and two control treatments. The permanent set-aside treatments were: natural regeneration of a "cover" crop in the winter barley stubble, sown perennial ryegrass and sown white clover. The rotational Set-aside treatment will be started after winter barley is harvested in 1993. The control treatments were continuous winter barley, and mixed arable/grass rotation of 2 years winter barley/spring barley undersown with ryegrass/2 years cut grass.

In order to allow for year-to-year environmental variation on the establishment of the green cover, its maintenance and in the response of the following crops to nitrogen fertiliser, the trial was laid down over a period of three years with two replicates being established in the autumn of 1989, 1990 and 1991.

The winter barley control was sown on 2 October 1989 and again in the same plots on 5 October 1990. Nitrogen was not applied to the seedbed of winter barley, but 180 kg/ha was top-dressed in spring in each year. The perennial ryegrass and clover plots were sown in April 1990, following ploughing and normal seedbed preparation. The second and third sets of ryegrass and clover replicates were sown in April 1991 and April 1992 respectively without ploughing as the extent of cover with chickweed was not as great as in April 1990. The ryegrass variety Preference PRG was broadcast at a rate of 15 kg/ha, half the normal rate, while 4 kg/ha of Huia white clover were also broadcast.

Each of the above 6 main plot treatments will be split for 7 nitrogen levels in the test period, after harvesting winter barley in 1994 in the first block, using winter wheat as the test crop in the first year and winter barley in the second year. A seventh replicated main plot treatment, identical to the clover treatment, was also established in each year in order to allow residual effects of nitrogen fertiliser application during the test cropping years to be investigated.

Soil and plant sampling and analysis

Concentrations of nitrate-N and ammonium-N in soil cores taken from depths of 0-15, 15-30 and 30-40 cm were determined at seven dates between August 1990 and February 1992.

10 g sieved, moist soil (< 6.4 mm) were shaken with 50 ml 1 M potassium chloride solution for 2 h in an end-over-end shaker and the extract filtered through No. 40 Whatman filter paper. The filter papers were washed with 25 ml 0.25 M potassium chloride solution to remove traces of ammonium (Qasim and Flowers, 1989) prior to filtering the extract. The nitrate-N in the soil extract was reduced to nitrite by passing over a copper-coated, cadmium wire and the concentration of nitrite was determined colorimetrically by a diazotization reaction on an auto analyser (Stainton, 1974).

Winter barley plants were sampled on 5 December 1990 and analysed for nitrogen content using mass spectrometry (Barrie et al., 1985).

RESULTS

The quantities of soil mineral nitrogen (nitrate + ammonium) at a depth of 0 to 40 cm under each treatment after harvest of the winter barley control are given in Table 1. The quantities of nitrate in the soil at a depth of 0 to 30 cm and 30-40 cm under each treatment in the set-aside established in autumn 1989 are given in Table 2. The quantities of nitrate in the soil at 3 dates between August 1991 and April 1992 under each treatment in the set-aside established in 1989 and 1990 are compared in Table 3.

TABLE 1. Soil mineral nitrogen to a depth of 40 cm under different green cover managements (kg/ha)

Green cover		Soil mineral nitrogen	
		21 Aug 90	26 Aug 91
Natural regeneration	(a)	13.3	24.8
	(b)		28.5
Grass	(a)	6.7	34.0
	(b)		17.5
Clover	(a)	10.9	48.5
	(b)		29.6
Winter barley	(a)	23.4	35.0
	(b)		30.9
Mean grand		13.6	31.1
year	(a)		35.6
	(b)		26.6
SED green cover		2.47	3.56
year			2.52
green cover x year			5.04

(a) set-aside autumn 1989; (b) set-aside autumn 1990

TABLE 2. Nitrate-N in soil to a depth of 30 cm and 30-40 cm (in parentheses) under different green cover managements (kg/ha)

Green cover	Nitrate-N			
	21 Aug 90	27 Sept 90	5 Dec 90	19 Feb 91
Natural regeneration	4.7 (3.3)	15.5 (3.4)	17.8 (9.7)	15.2 (6.5)
Grass	2.3 (0.7)	1.8 (1.3)	6.9 (3.0)	8.7 (1.2)
Clover	5.0 (2.8)	18.1 (4.2)	33.8 (14.2)	22.9 (10.6)
Winter barley	15.8 (4.6)	29.6 (12.4)	18.3 (10.9)	13.1 (6.7)
SED	1.91(1.27)	3.23(0.74)	4.31(1.3)	3.75 (0.41)

TABLE 3. Comparison of nitrate-N in soil to a depth of 30 cm and 30-40 cm (in parenthesis) under Set-aside established in two different years (kg/ha)

Green cover		Nitrate-N		
		26 Aug 91	28 Oct 91	13 April 92
1. Natural regeneration	(a)	17.4 (3.7)	11.6 (1.5)	9.4 (0.5)
	(b)	13.4 (7.7)	9.9 (2.8)	15.3 (7.4)
2. Grass	(a)	21.7 (8.3)	16.1 (11.9)	7.9 (10.7)
	(b)	8.9 (6.7)	17.5 (5.0)	6.9 (7.4)
3. Clover	(a)	37.4 (6.2)	34.0 (5.2)	39.8 (9.0)
	(b)	12.3 (13.5)	6.9 (5.8)	23.2 (12.6)
4. Winter barley	(a)	26.9 (4.7)	28.9 (2.5)	36.4 (2.8)
	(b)	20.0 (8.6)	18.3 (10.7)	24.1 (14.6)
Mean grand		19.8 (7.4)	17.9 (5.7)	20.4 (8.1)
green cover	1	15.4 (5.7)	10.8 (2.2)	12.4 (4.0)
	2	15.3 (7.5)	16.8 (8.4)	7.4 (9.0)
	3	24.8 (9.8)	20.4 (5.5)	31.5 (10.8)
	4	23.4 (6.6)	23.6 (6.6)	30.2 (8.7)
Year	(a)	25.8 (5.7)	22.6 (5.3)	23.4 (5.8)
	(b)	13.6 (9.1)	13.2 (6.1)	17.4 (10.5)
SED green cover		3.73(1.45)	4.12(2.59)	5.35(4.03)
year		2.64(1.03)	2.91(1.83)	3.79(2.85)
green cover x year		5.28(2.06)	5.82(3.66)	7.57(5.70)

(a) set-aside autumn 1989; set-aside autumn 1990

DISCUSSION

The lack of a growing cover in the winter barley stubble is shown in the August samplings (Table 1), where there were 16.7 and 13.3 kg/ha mineral nitrogen more in the soil under the stubble than under the first-year grass in 1990 and 1991 respectively. However, the mineral nitrogen was 16.7 kg/ha more under the second-year grass than under the first-year grass in August 1991. Sampling in August 1992 will be used to test whether there is a sustainable build-up of mineral nitrogen under the cut grass with age of the grass, or whether the difference found in August 1991 is typical of the differences in the soil between the two set-aside areas.

There were 11.6 kg/ha more nitrogen under winter barley after harvest in 1991 than 1990. A similar increase in nitrogen was found under the natural regeneration whereas the increase under clover was 37.5 kg/ha. There were only 35 mm of rainfall during July 1990 compared with 99.8 mm during July 1991, while air and soil temperatures were similar. Mineralisation rate may have been greater in the more moist soil during July 1991, resulting in a higher residue of mineral nitrogen.

Data on the potential for nitrate leaching are given in Table 2. The nitrate-N to a depth of 30 cm is available for plant uptake, but has the potential to be leached. The sharp increase between 21 August and 27 September observed in all plots, except the grass, is a consequence of the management treatments between these dates, ie ploughing in the barley and cutting on the other plots. Ploughing promoted mineralisation of soil nitrogen and cutting the return of 'locked up' nitrogen from the plant material to the soil. The most effective cover was grass. Between 27 September and 5 December barley plants removed 18.3 kg/ha of nitrogen (calculated from analysis of the plants). As the nitrate-N present on 5 December is at greatest risk from leaching because the growth of all the cover crops is minimal at this time and the soil is wet, then the highest loss of nitrate-N is likely to occur under clover which was confirmed by the February 1991 data. The nitrate-N in the subsoil (depth 30-40 cm) can be considered as leached nitrate, as few plant roots were observed at this depth. These results reflect those for the upper 30 cm (Table 2) but give a better indication of the quantity of nitrate which will enter the nearest watercourse.

There was more nitrate under the clover, established in the 1989 set-aside, than under other treatments between August 1991 and April 1992 (Table 3). This was in contrast to the nitrate under clover established in the 1990 set-aside. This may be a reflection of the poorer establishment and cover of clover in the 1990 set-aside.

CONCLUSION

In the Set-aside established in autumn 1989, our data showed that, from the point of view of minimising loss of nitrate-N from set-aside land, grass is a better cover crop than clover or natural regeneration. Also under continuous winter barley there was an increase in the amount of nitrate-N leached after ploughing in September 1990, an effect not seen under set-aside land. Data from the set-aside established in autumn 1990 were sufficiently different from the earlier set-aside to highlight the potential variation from year-to-year.

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CHANGES IN HYDROLOGY, PESTICIDES AND SOIL-NITROGEN LEVELS UNDER SET-ASIDE

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ABSTRACT

The effect of the conversion of arable clayland to long term set-aside on the soil-hydrology and on the leaching of nitrate and pesticides has been examined in a long term experiment. Under set-aside, rapid reductions in soil-mineral nitrogen (SMN) were observed from fields previously in winter cereals. Following a winter bean crop, higher SMN levels were observed and were reflected in enhanced nitrate-N (NO_3-N) leaching in drainage water. Winter NO_3-N concentrations were generally observed to fall below the EC Drinking Water Directive limit within 12 months of set-aside establishment. Pesticide concentrations in excess of the EC Directive were, however, occasionally observed for several urea herbicides and for one insecticide for at least one year in set-aside. Early data suggests that conversion to set-aside leads to a deterioration in drainage status and increased peak runoff.

INTRODUCTION

Until the mid 1980's, agriculture was generally becoming more intensive with widespread use of inorganic fertilisers and agrochemicals. Their use, together with increased investment in drainage, aided improved crop production. One effect noted for drained cropped systems was that the route by which excess water was removed from clayland could be altered with the peak runoff to surface waters reduced due to increased soil storage (Arrowsmith et al., 1989). Harris et al. (1988) also showed that, without cultivations, surface compaction combined with improved clayland sub-soil structure could lead to more rapid runoff.

However, such changes in runoff have been shown to influence the loss of agrochemicals. Rose et al. (1991) found that the greater soil-water contact and mineralisation resulting from tillage increased NO_3-N losses over those from non-intensive systems and particularly mature woodland. This implies that the introduction of agricultural set-aside in the UK, after 1988, (Clarke & Cooper, 1992) is likely to cause important changes in soil structure, runoff and the accompanying loss of nutrients and agrochemicals. An experiment was initiated in 1989 with the principal objective of identifying the impact of these potential changes under 5 year 'permanent' set-aside in clay soils. The work complements a wider programme reported by Clarke & Cooper (1992) and will support MAFF Policy decisions and assist other field and modelling studies examining the factors influencing the loss of nutrients and agrochemicals to surface waters.

MATERIALS AND METHOD

Site Description

The clayland site at Conington, Cambridgeshire consisted of a farm unit of approximately 220ha converted from cropping to natural regeneration permanent set-aside after harvest 1988, with the exception of 12ha which remained in winter wheat for a further year. The vegetation was typically cut once a year in July or August. Within the unit, two discrete catchments were instrumented, CN1 (20ha) and CN2 (30ha), which included the 12ha of winter wheat described above. At nearby Swavesey (Harris et al., 1991), a 500ha predominantly clay catchment remained cropped throughout the study period and provided a control site which included 250ha of land at Highfield with similar soils and cropping prior to set-aside at Conington.

Farm management records at both sites included details of the drainage, nutrient and agrochemical applications since 1984. At all sites, mole drainage over pipe-drains (typically at 900mm depth) had been installed in most fields. Prior to set-aside, a range of crops with emphasis on winter wheat and winter barley was grown, with different fertiliser and pesticide applications. Average nitrogen fertiliser application rates for winter wheat and winter barley are given in Table 1.

TABLE 1. Nitrogen fertiliser applications (kg/ha N) to winter wheat (WW) and winter barley (WB) at Swavesey, harvest years 1987, 1988 and in the harvest year 1988 preceeding set-aside at Conington.

		1986/87	1987/88	1988/89	1989/90	1990/91
Conington	(WW)	-	155	Set-aside ---------------->		
	(WB)	-	170	Set-aside ---------------->		
Swavesey	(WW)	180	194	205	198	205
	(WB)	140	142	177	163	175

Runoff

Runoff from the set-aside catchments was monitored using Parshall flumes. Ditch responses were measured continuously at Swavesey; flow records were available following the installation of a similar flume at Highfield in 1990. Rainfall was also recorded at both sites.

Field sampling grid

A quadrat grid system based typically on 9-12 locations was established. In Highfield this provided permanently marked sampling locations for 50% of the fields whereas at Conington all fields in the catchments were marked. In the remaining 170ha under set-aside at Conington, sampling was undertaken on a random basis. This grid system was used for soil sampling to characterise in-field and boundary soil mineral nitrogen (SMN) to 900mm depth; samples were analysed for NO_3-N and NH_4-N (MAFF, 1986). It also characterised the depth to the water-table and ground cover in 1m² quadrats under set-aside (Brodie et al., 1992). Soil variations were assessed at these grid points.

Water sampling and analysis

Water samples to determine NO_3-N and pesticide residue concentrations were initially collected manually and later automatically by programmable samplers using the techniques described by Harris et al. (1991). Samples of 30ml volume, to determine NO_3-N concentrations, were collected daily except in 1990/91 and during storm events. Analysis was by a flow injection system as described by Harris and Parish (1992). Pesticide samples (1-2.5 litre) were analysed by high performance liquid chromatography (hplc), gas chromatography (gc) and mass spectrometry (ms) techniques; the extraction, analysis and confirmation procedures adopted are described by Harris et al. (1991). Analytical quality assurance, recovery and storage stability experiments were also undertaken. The active ingredients selected for analysis were consistent with those studied in the other catchment studies. These were the aryloxyalkanoic acid herbicide mecoprop, the urea herbicides isoproturon, chlorotoluron and linuron, the triazine herbicides atrazine and simazine, and the organophosphorus insecticide dimethoate.

RESULTS

Hydrology

Changes in peak runoff following the conversion to set-aside were assessed at Conington by comparison with the nearby control sites. Runoff was markedly influenced by the very low rainfall, with soil water-tables at both Conington and Swavesey below drain depth for most of the two winters 1989/90 and 1990/91 (Fig. 1). However, in January 1992, following 40mm rainfall in 36 hours, the depth to the water-table was notably less at Conington than similar land at Swavesey. This was reflected in runoff which was much peakier at Conington, with both extensive surface flows and rapid drainflow (Fig. 1). At Conington, surface runoff was extensive with ponding near to field boundary ditches. At the same time, however, water movement down the soil profile resulted in a rapid drainflow response. At Swavesey, no drainflow occurred; most runoff originated from farm tracks.

Nitrogen loss

Under set-aside at Conington, relatively rapid reductions in SMN levels were seen, especially in land previously in winter wheat or barley crops. Here SMN in the clay soil, after one year of set-aside, was typically 35kg/ha N, although 85kg/ha N was initially measured in the 12ha of winter wheat in catchment CN2. In areas of winter beans prior to set-aside, the comparable SMN was 50 kg/ha N. These compare to typical values at Swavesey of 100-125kg/ha N for established fields of winter cereals (Table 2). Comparison of areas of particularly good regeneration growth with areas where this was poor, showed about 15kg/ha N less SMN under the former. By autumn 1991, less variation between fields was observed in the SMN values suggesting that the site was reaching equilibrium between vegetation nitrogen uptake/return, soil processes and atmospheric inputs/outputs. Losses of NO_3-N from both catchments at Conington, given in Fig. 2, were higher in catchment CN2, where 12ha remained in cropping for a further year and received inorganic fertiliser applications.

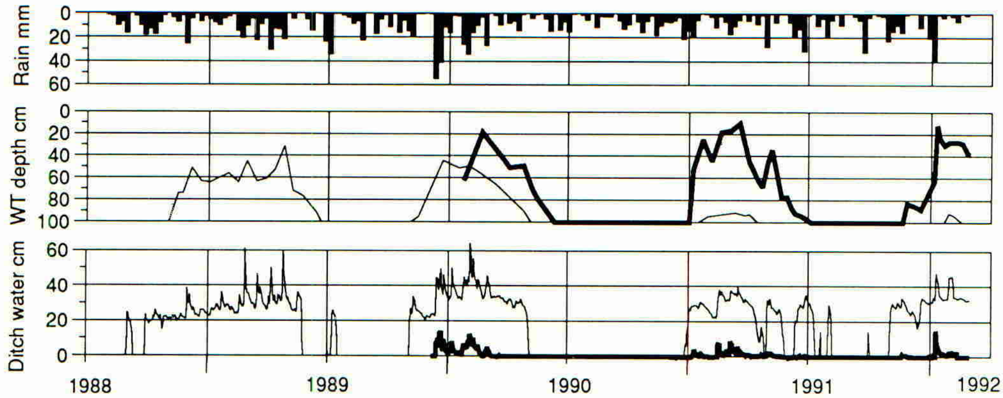

Fig. 1. Rainfall, water-table control and catchment runoff response —— Swavesey (arable); ▬▬ Conington (set-aside).

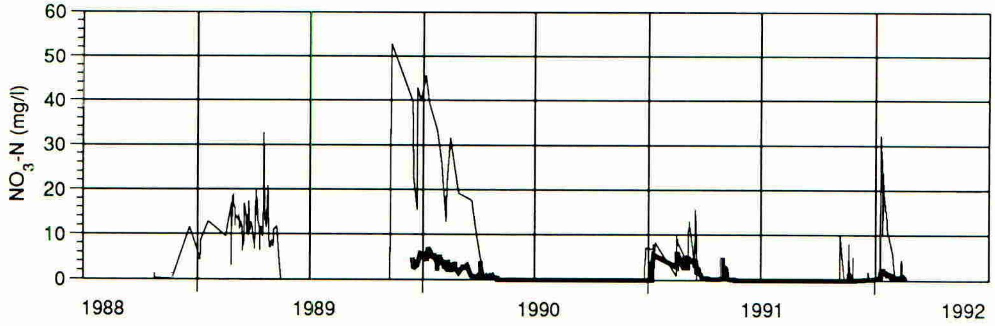

Fig. 2. Losses of NO_3-N in runoff; —— Swavesey 1988-92 (arable) ▬▬ Conington 1989-91 (set-aside)

TABLE 2. SMN (kg/ha N) by crop and catchment at Conington under set-aside and in cropping at Highfield, Swavesey in spring and autumn.

Last crop harvested 1988	Conington - set-aside spring 1989	autumn 1989	autumn 1990	autumn 1991	Highfield - arable farming spring 1989	autumn 1989	autumn 1990	autumn 1991
W. Wheat	35	30	30	20	160	74	47	125
W. Barley	-	-	-	-	90	95	74	80
S. Barley	40	35	25	15	-	-	-	-
W. Beans	55	45	40	20	-	67	-	-
12ha area	150	90	35	25				
CN1	30	25	20	15				
CN2	35	30	25	15				

Concentrations initially exceeded the EC Drinking Water Directive limit of 11.3 mg/l NO_3-N (Anon., 1980) but rapidly fell below. In contrast, under arable cropping at Swavesey, concentrations exceeded the EC limit for much of the season. In those fields where enhanced SMN was observed at Conington, eg. following winter beans, NO_3-N concentrations in field drains were notably higher. The highest concentration recorded was 33 mg/l NO_3-N in spring 1989.

Pesticide losses

Pesticide residues of the two urea herbicides isoproturon and chlorotoluron only were detected in the catchments at Conington under set-aside. Within the whole unit dimethoate was also found in drainage discharge. Most detections were made in the first spring of set-aside or in the first runoff of the following season (autumn 1989) and therefore the loss represented a flush effect from the soil. In this period, the highest concentration detected was 0.2 µg/l for isoproturon. By spring 1991, no further detections were made for pesticides with the exception of chlorotoluron on one occasion; it was thought that spray drift from adjacent farmed land may have been the source. By contrast in both areas at Swavesey, detections above the EC limit were made each year for several of the applied pesticides, particularly isoproturon and simazine (Harris et al., 1991).

DISCUSSION AND CONCLUSIONS

The rapid reduction in SMN seen under permanent set-aside can have good effects on the environment. Under natural regeneration with cut crop residues returned to the soil surface, improvements in NO_3-N concentrations in drainage water were seen in the first year of set-aside compared to cropped land. Similar results were reported by Catt et al. (1992) in drainage runoff from unfertilised seeded grass following continuous winter cereals, but only after the grass had become established. At Conington however, nitrogen mineralisation would have been much reduced as the regenerated cover was established in the crop stubble without cultivations. The enhanced SMN and leaching observed under set-aside following the bean legume crop demonstrated that although NO_3-N concentrations were lower than in cropped land, the nitrogen fixing properties can delay water quality improvements. Although the losses of pesticides recorded under set-aside were relatively small compared to those in managed farmland (Rose et al., 1991), the presence in particular of the urea herbicide isoproturon at concentrations above the EC Drinking Water Directive limit of 0.1 µg/l for a single pesticide (Anon., 1980) gives evidence that losses to surface waters can occur for at least one year after the last application.

A similar increase in flood risk to that seen at Conington has been reported by Harris et al. (1988) for cropped clayland managed with minimal cultivations. They found that surface compaction due to lack of autumn cultivations led to the enhanced development of surface runoff, but at the same time the development of an improved structure in the sub-soil resulted in more rapid water movement to the drainage system through the cracks. Without cultivations, broadly similar mechanisms for water movement can occur under set-aside. The impact on the flood risk is important in that a whole catchment approach to improve water quality, for example to meet the proposed EC Directive on Surface Waters, must take into account the potential impact on the hydrology. Whereas set-aside can give positive water quality benefits, the change in flood runoff may need to be balanced against this benefit. For example, similar positive water quality benefits can also be obtained from clayland converted to mature woodland (Rose et al., 1991), but concerns have been expressed that the increased water usage by trees could lead to a reduction in surface runoff or aquifer recharge.

It is concluded that the full environmental benefits associated with agricultural systems such as set-aside will only be obtained within a managed catchment approach by balancing drainage, runoff and water quality needs.

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EFFECT OF SET-ASIDE ON DISEASES OF CEREALS

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ABSTRACT

A survey of set-aside fields produced no firm evidence to suggest that infected volunteers on such fields acted as major sources of disease for adjacent cereal crops. In a series of replicated trials, both take-all and eyespot tended to be less severe after a 'natural regeneration' set-aside treatment, or after ryegrass, than after continuous wheat. Take-all, however, was reduced less effectively by these treatments than by a bare fallow. In a trial where moderate levels of mildew occurred, the disease was least severe after that treatment (ryegrass) which left least residual nitrogen in the soil.

INTRODUCTION

Putting a field into set-aside may be expected to affect cereal diseases in three distinct ways: (i) infected plants on the set-aside land could act as sources of disease for neighbouring crops of the same species, (ii) the use of rotational set-aside could provide a break in a cereal sequence and thus reduce risks of disease (particularly root disease) in the crops taken after the period of set-aside, (iii) management practices during the set-aside period could, through their effects on soil fertility, affect disease development in subsequent crops by influencing the plants' susceptibility to infection. A MAFF survey of set-aside land carried out by ADAS in 1991 and the Rotational Fallow Experiments carried out on ADAS Research Centres (Clarke & Cooper, 1992 - provided opportunities to assess the effects of set-aside both on crops adjacent to the set-aside land and on crops following set-aside.

METHODS

The survey

As part of a comprehensive survey of set-aside land initiated by MAFF, observations were made in April and May 1991 on 22 sites in southern and eastern England. Assessments were made of disease levels on cereal volunteers on the set-aside fields. Adjacent fields carrying crops of the same species were examined for evidence of disease gradients which would indicate that the infected volunteers had been the source of the disease. This examination was based on disease assessments made on 3 leaves on each of 3 tillers taken at intervals along traverses (3 in each field) running at right angles to the edge of the set-aside land. Samples were taken every 5m for the first 50m, every 10m for the next 100m and at 20m intervals thereafter.

The experiments

In spring, before the main nitrogen application, 25 to 30 plants from each of the fallowing/set-aside treatments were assessed for leaf, stem base and root diseases. In summer (GS 75) similar assessments were carried out on 10 plants from each of the nitrogen sub-plots. Eyespot and take-all indices were calculated using formulae based on that of Scott & Hollins (1974).

RESULTS

Set-aside land as a source of inoculum for neighbouring fields

Though infected volunteer plants could be found without difficulty on most of the set-aside fields surveyed, attempts to implicate these volunteers as sources of inoculum for adjacent fields proved inconclusive. Data obtained from the survey are summarised in Table 1.

TABLE 1. Disease gradients in fields adjacent to set-aside land (disease levels correlated with distance from set-aside)

Disease	Negative correlation coefficients		Positive correlation coefficients	
	Number	Mean value	Number	Mean value
Mildew	11	0.389	9	0.310
Septoria	4	0.179	3	0.358
B. rust	3	0.191	1	0.088
Y. rust	1	0.287	0	-

While in some instances disease levels declined with distance from the set-aside land, this effect was neither strong nor consistent and in many instances disease could be more closely correlated with variations in topography and/or soil fertility. The survey thus failed conclusively to demonstrate that the proximity of a set-aside field was having an over-riding influence on disease levels in nearby crops. It is possible, however, that disease gradients established in the autumn had been lost by the time the observations were made.

Effect of set-aside on disease levels in subsequent crops

Take-all

Of all the diseases of cereals, take-all (Gaeumannomyces graminis) might be expected to be most influenced by the management of set-aside. Normally well controlled by a one year break, it builds up in the first few years of a cereal sequence and then declines (Glynne & Cox, 1959). The possible effects of set-aside on take-all illustrate the complexity of management x disease interactions. (a) By acting as a break in the cereal sequence, set-aside would reduce the level of inoculum in the soil. The effectiveness of this would depend, however, on the number of volunteers surviving to carry the pathogen through the set-aside year. (b) Set-aside introduced into a run of cereal crops could prevent the development of take-all decline (again this could be influenced by the presence or absence of volunteers). (c) Ryegrass grown during the set-aside year might serve to carry the take-all fungus through the break. However, the build up of the antagonistic fungus Phialophora graminicola on the roots of the grass could suppress the disease in subsequent crops (Deacon, 1973). (d) the effects of set-aside treatment on soil nitrogen could affect take-all in two ways: (i) effects on available soil nitrogen in the set-aside year could affect the ability of the fungus to survive as a saprophyte on dead root debris; (ii) effects on residual soil nitrogen could affect the susceptibility of any subsequent cereal crop to infection (Hornby, 1985).

In the ADAS Research Centre trials take-all levels were low at Bridgets (BR) and High Mowthorpe (HM) and interpretation of the data from Gleadthorpe (GT) is hampered by the absence of a continuous wheat treatment at this site. Data from Boxworth (BW) and Drayton (DT) are presented in Table 2. (For trial design see Clarke & Cooper 1992).

TABLE 2. Effect of set-aside and fallowing treatments on take-all

	BOXWORTH					DRAYTON				
	Phase 1		Phase 2		Phase 3	Phase 1		Phase 2		Phase 3
	1989	1990	1990	1991	1991	1989	1990	1990	1991	1991
Test year:-	1	2	1	2	1	1	2	1	2	1
Wheat crops prior to set-aside	3		2		1	2		4		2
Sown	5/10	27/9	1/11	28/9	8/10	4/10	25/9	27/9	10/10	10/10
TAKE-ALL INDEX AT GS 75:-										
Cont. wheat	24	26	22	42	23	45	41	26	42	39
Ryegrass	18	27	18	35	23	28	34	21	29	38
Natural regen.	31	25	9	23	21	-	-	23	34	22
Bare fallow	15	15	8	13	5	23	49	25	23	15
Sprayed fallow	26	24	-	-	-	24	48	-	-	-
Legume	-	-	-	-	-	-	-	20	23	14
SED	6.3	3.3	3.6	4.7	8.8	7.7	6.6	2.8	5.2	3.5

Treatment effects on take-all were less pronounced than might have been expected but, in the first year after treatment, disease indices were invariably highest (mean 38) in the continuous wheat and lowest (mean 18) after bare fallow. Indices after natural regeneration (mean 21) and ryegrass (mean 24) tended to be between these two extremes suggesting that the volunteer plants in the one treatment and the grass in the other were acting as hosts for the fungus. Phialophora graminicola is known to have been present where the ryegrass was grown (R. Gutteridge, IACR, pers. comm.). This antagonist of the take-all fungus was more in evidence at Drayton than at Boxworth but even on the former farm it was far from abundant. It would seem that, in these trials, a single year of grass cropping was insufficient for P. graminicola to build up to such levels as would allow it to suppress the disease.

Eyespot

The eyespot fungus (Pseudocercosporella herpotrichoides) can survive in the absence of host plants far more readily than will G. graminis. Infected debris ploughed under before a break will still remain infective when ploughed up again a year later. High nitrogen levels render the plants more susceptible to infection (Cunningham, 1983). Nitrogen applied in spring can, however, reduce the final eyespot level by stimulating tillering when conditions are less conductive to infection (this was supported by data from the nitrogen sub-plots in the trials).

Eyespot levels in the ADAS Research Centre trials were very variable. Data for the first test years from trials where appreciable levels of the disease were present are presented in Table 3.

TABLE 3. Effects of set-aside and fallowing treatments on eyespot
P = % plants infected, S = % stems infected, I = index

Site	Year			Continuous wheat	Ryegrass	Natural regen.	Bare fallow	Sprayed fallow	Legume	SED
BW	89	spring	(P)	50	15	32	34	26	-	3.9
	90		(P)	23	18	17	42	-	-	3.7
	91	spring	(S)	33	8	5	11	-	-	4.3
		summer	(I)	20	6	6	14	-	-	3.5
DT	89	spring	(I)	11	8	-	17	5	-	7.5
		summer	(I)	9	5	-	15	8	-	3.2
HM	89	spring	(P)	16	5	6	2	-	-	4.2
		summer	(I)	11	4	6	7	-	-	2.1
BR	91	summer	(I)	21	13	17	18	-	14	3.5

In every case eyespot levels were lower after the set-aside and fallowing treatments than in the continuous wheat. Although the differences did not always reach the level of statistical significance, there was a tendency for there to be more disease after the bare fallow (which would be ploughed both before and after the treatment year) than after the natural regeneration or sprayed fallow treatments in which inoculum from the previous cereal crop would have been left on the surface during the treatment year and ploughed under before the first test crop was taken.

Since eyespot infection takes place from autumn onwards, the incidence of the disease is also likely to have been influenced by the effects of the treatments on soil nitrogen levels in the autumn and winter following the treatment year. Estimations of soil mineral nitrogen measured in kg SMN/ha) carried out in November in the first test years have been reported by Froment & Grylls (1992). Averaged over the three years and across all five sites, and expressed as a percentage of the values for the continuous cereal treatment, these estimations gave the following figures: bare fallow 154, topped stubble 103, ryegrass 60. These differences in SMN may have affected the susceptibility of the following year's wheat to infection by the fungus.

Treatment differences noted in the first test year sometimes, though not invariably, persisted through into the second. This is illustrated by the data from Boxworth presented in Table 4.

TABLE 4. Effects on set-aside and fallowing treatments on eyespot (BW) P = % plants infected, S = % stems infected,

Phase	Test year	Year		Continuous wheat	Ryegrass	Natural regen,	Bare fallow	Sprayed fallow	SED
1	1	89 spring	(P)	50	15	32	34	26	3.9
	2	90	(S)	68	60	55	62	60	3.4
2	1	90	(P)	23	18	17	42	-	3.7
	2	91	(S)	20	19	15	23	-	3.4

<u>Leaf diseases</u>

The spores of powdery mildew (<u>Erysiphe graminis</u>) and the rusts (<u>Puccinia</u> spp) are readily spread by wind, as indeed are the ascospores of the perfect stage of <u>Septoria tritici</u>. For this reason the effect of set-aside treatment on the survival of inoculum is less important than is the case with the soil-borne diseases. The ADAS Research Centre trials were sprayed routinely against foliar diseases and, in general, the levels of such diseases recorded in them were very low. However, in the spring of 1989 moderate levels of mildew were recorded in the first test year at Gleadthorpe (Table 5).

TABLE 5. Effect of set-aside treatment on mildew - Gleadthorpe 1989

	Oats	Ryegrass	Natural regen	Bare fallow	Sprayed fallow	Forage rape	SED
SMN*	100	57	131	198	-	112	
% mildew (leaf 3)	20	16	19	24	23	20	2.7

*mean values for Gleadthorpe - oats = 100% (Froment & Grylls, 1992)

While the fit is not perfect, the data suggest that the differences in mildew levels are associated with the effects of treatment on soil mineral nitrogen. Increasing N will increase the susceptibility of the plants to infection.

DISCUSSION

Despite the findings of the MAFF survey it has to be accepted that infected volunteers on set aside land are potential sources of over wintering leaf diseases for neighbouring fields. For mildew and Septoria the general level of inoculum in the countryside is such that the additional spore load from set-aside is likely to be of little consequence. For yellow rust, on the other hand, the importance of infected volunteers as a source of inoculum as long been recognised (Gair et al. 1983) and could be of particular importance in the early dissemination of new strains of the pathogen. The sowing of grasses or legumes, rather than simply allowing natural regeneration on the fields should, however, greatly reduce the importance of set-aside as a source of disease inoculum.

The effect of rotational set-aside on disease in subsequent cereal crops is likely to be largely beneficial. The presence of high populations of volunteers will minimise these benefits, sowing the land to a non-graminaceous species for the set-aside period will maximise them.

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A COMPARISON OF WINTER WHEAT YIELDS FROM HEADLANDS WITH OTHER POSITIONS IN FIVE FEN PEAT FIELDS

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ABSTRACT

A 1988 experiment at ADAS Arthur Rickwood compared yield and quality at four positions on the headlands with two positions in the main body of five fields of winter wheat each containing different varieties. All crops followed a non-cereal crop. The yield of different varieties in different fields varied markedly (range 4.50 to 7.09 t/ha). There were highly significant ($P<0.001$) yield differences between the headlands and the main bodies of the fields with a general trend for yield to increase as the position of measurement moved further into the fields. The results are presented and discussed. Some factors that might affect the comparisons on this and other sites are considered and the influence of the results on farmers and policy makers considering the effect of headland set-aside is explored briefly.

INTRODUCTION

After 4 years of the two set-aside schemes a total of about 167,000 ha of land is now set-aside in the UK (Clarke & Cooper, 1992). At an average UK yield of all cereals of 5.8 t/ha this would produce a cut in production of 968,600 tonnes. At different times in the formulation of set-aside policy, consideration has been given to the idea of allowing producers to set-aside headlands as opposed to whole fields. It is generally presumed that the yield from headlands is lower than the main body of the field due to such factors as excessive wheelings during cultivation, spraying and fertiliser application as well as the competitive effect of hedgerows. Thus headland set-aside would give a lower reduction in production per unit area than whole field set-aside. In order to inform this debate, an experiment was conducted in 1988 at the Arthur Rickwood research centre to evaluate the yield from different areas of five fields of winter wheat each following a non-cereal break crop. The experiment also examined whether there was any difference in the yield obtained from plots marked out on headlands where a tractor mounted sprayer was turned compared with those where it was not.

METHODS

In each field, 2.8m by 30m plots were marked out at the positions shown in Table 1. The plots were positioned in blocks on different headlands so that they either ran parallel with the path of the tractor mounted sprayer or at right angles to it. Yields were measured using a plot combine harvester and corrected to 85% d.m. on the basis of a sub-sample. Specific weight, as kg per hectolitre (hl), of the grain was also measured. A split plot design was used, with sprayer direction as main plots which were split for the distance of the plot from the field edge. There were five replicate fields, details of which are given in Table 2.

TABLE 1. Plot locations.

Plot Code	Distance from field margin (m)
a	1.0 - 3.8
b	4.8 - 7.6
c	8.6 - 11.4
d	12.4 - 15.2
e	20.2 - 23.0
f	24.0 - 26.8

TABLE 2. Field details.

Field	Soil Type	% o.m.	Variety	Sowing Date	Previous Crop
Big Ground South	Peaty Loam	37	Alexandria	15.12.87	Onions
House Ground	Peaty Loam	35	Slejpner	4.12.87	Potatoes
North Toll	Organic Loam	12	Hornet	16.10.87	Spring beans
Owen's Piece	Peaty Loam	29	Brock	14.10.87	Potatoes
Phipp's Meadow	Peaty Loam	34	Mercia	6.10.87	Spring beans

RESULTS AND DISCUSSION

The yields and specific weights are given in Tables 3 and 4 with the statistical data in Table 5. Mean field yields as calculated from the sum of weighed loads of grain from each field, each corrected to 85% d.m., and divided by the field area are given in Table 6.

There were significant ($p<0.001$) differences between mean field yields. There was no yield difference between plots harvested parallel with the wheelings of the tractor mounted sprayer and those harvested across the wheelings. This is surprising given the fact that the latter included areas where the sprayer had turned on the headland with consequent high levels of apparent crop damage from wheelings.

There were significant ($p<0.001$) differences between the yields recorded at different positions from the field edge. Generally, the further the position into the field, the higher the yield. Over all fields and varieties there was a mean yield increase of 0.9 t/ha when comparing the area between 20 and 26m from the field edge with the area between 1 and 7m from the field edge. The highest yield difference in this comparison was 1.8 t/ha. The exceptions to the general pattern were the two lowest yielding fields. In Owen's Piece the two positions nearest the field edge gave lower yields than the others which had similar yields. In Phipp's Meadow, there were no real differences between the different positions. There were differences in quality between the five fields which reflected the variety being grown, but there were no treatment effects.

The figures in Table 6 represent our best estimate of the mean yield of each field. There would have been a cut in production of 97 tonnes that would have accrued from taking all the fields out of production in 1988,

TABLE 3. Grain yield (t/ha) parallel (P) to the path of the sprayer or at right angles (R) to it in Big Ground South (BGS), House Ground (HG), North Toll (NT), Owen's Piece (OP) and Phipp's Meadow (PM).

Position	Field BGS		HG		NT		OP		PM	
	P	R	P	R	P	R	P	R	P	R
a	5.63	5.70	6.28	6.70	7.02	6.88	4.69	4.89	4.75	4.66
b	6.26	6.46	4.88	6.62	7.22	6.46	4.09	4.80	4.71	4.48
c	7.12	6.68	6.77	6.04	7.00	6.54	5.16	5.95	4.06	4.65
d	7.89	7.04	7.11	7.54	7.78	6.79	5.79	6.07	4.12	4.85
e	7.87	7.50	7.54	7.87	7.80	7.38	5.82	5.35	4.26	4.39
f	8.09	7.75	7.33	7.63	7.72	6.56	5.61	5.45	4.85	4.25
Mean	7.14	6.86	6.65	7.07	7.42	6.77	5.19	5.42	4.46	4.55
Field Mean	7.00		6.86		7.09		5.31		4.50	

TABLE 4. Specific weight (kg/hl) parallel (P) to the path of the sprayer or at right angles (R) to it in Big Ground South (BGS), House Ground (HG), North Toll (NT), Owen's Piece (OP) and Phipp's Meadow (PM).

Position	Field BGS		HG		NT		OP		PM	
	P	R	P	R	P	R	P	R	P	R
a	80.7	81.4	74.4	76.2	74.8	74.6	74.5	75.4	72.4	78.4
b	79.7	79.9	76.1	76.7	74.7	74.8	74.9	76.6	72.3	78.4
c	79.1	79.2	76.3	77.5	75.0	75.7	76.1	77.3	73.1	72.6
d	79.2	79.2	76.6	78.7	74.2	73.8	76.3	76.3	73.3	75.6
e	80.0	78.6	77.5	79.4	74.0	73.7	76.1	75.6	72.8	74.4
f	80.9	79.5	77.3	77.7	75.9	71.9	75.8	76.2	72.8	73.8
Mean	79.9	79.6	76.4	77.7	74.8	74.1	75.6	76.2	72.8	75.5
Field Mean	79.8		77.0		74.4		75.9		74.2	

TABLE 5. Statistical analysis.

Factor	Yield (t/ha)	Specific weight (kg/hl)
CV%	8.9	2.0
SED (49 df) all fields		
sub plot comparison	0.578	1.79
sub plot means comparison	0.546	1.52
SED (10 df) each field		
sub plot comparison	0.258	0.80
sub plot means comparison	0.244	0.68

TABLE 6. Mean field yields and specific weight

Field	Area (ha)	Yield (t/ha at 85% d.m.)	Specific Weight (kg/hl)
Big Ground South	3.26	6.82	78.8
House Ground	4.38	6.40	75.0
North Toll	1.11	6.86	74.6
Owen's Piece	3.65	6.04	76.6
Phipp's Meadow	2.84	6.01	75.0

or a mean of 6.13 t/ha across all five fields. Because the figures in Table 6 were measured differently to those in Tables 3 and 4, a direct comparison is not possible. However, the data in Tables 3 and 4 suggest that setting-aside a 15m headland on each field would have produced a lower cut in production per ha than taking the complete fields out of production.

With regard to factors that might have affected the comparison, it should be noted that the soil types involved do not generally suffer from problems of compaction. The influence of competition from the field boundary is likely to have been minimal - Big Ground South had a hedge on three sides and House Ground on one, but all the other fields were bordered by a ditch or the crop of an adjacent field. We therefore suggest that the comparison was made in favourable circumstances in this case and it seems reasonable to hypothesise that the difference between yields from the headlands and from the main body of the field may be greater where a soil type more prone to compaction is involved and/or where the field is bordered by trees or a competitive hedge. It is also worth noting that where a headland set-aside system is practised some of the problems leading to the reduced headland yield, i.e. compaction and wheeling damage, could be transferred to the new headland at the edge of the cropped area of the field, thus reducing the yield of the cropped area, unless the set-aside is used for turning.

Headland set-aside does have the potential to influence the flora and fauna of the field margin and current work at Arthur Rickwood has the objective of examining the effects on the fenland ditch environment. If positive effects can be demonstrated then these will have to be taken into account, together with this and other yield data, in any further evaluation of the technique.

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THE EFFECT OF CULTIVATION AND PLANT ESTABLISHMENT ON NITROGEN CONSERVATION ON SET-ASIDE LAND

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INTRODUCTION

The EC decision to introduce the Set-aside Scheme was designed to take land out of cereal production. It was necessary to investigate different cropping and land management schemes to determine those that also minimised nitrate leaching loss.

Under the initial Set-aside Scheme, established in 1987 in the UK, farmers were allowed two options - 'rotational' (one year) and 'permanent' (three to five year) Set-aside. Farmers were required to ensure that the land must be kept in good order, must have a green-crop cover sown as soon as practicable after harvest, and receive no inorganic fertilizers or pesticides.

Results presented in this poster refer to the set-aside phase and show the effectiveness of a number of options in conserving N in the soil.

METHODS

To assess soil nitrate losses and problems of set-aside 'crop' management we established, in association with ADAS, a series of three consecutive one year set-aside experiments (Sites 1, 2 & 3) starting in 1988 on a sandy loam at Woburn in Bedfordshire.

Each experiment started with a one-year Set-aside treatment 'crop' (Phase 1) on three replicate blocks, followed by two test winter wheat crops (Phases 2 & 3). We established the following set-aside land management treatments as well as winter wheat (WW) as a control: autumn-sown forage rape (FR), autumn-sown ryegrass (RG), stubble with natural regeneration (TO), spring-sown trefoil (TR), shallow cultivated stubble (ST) and cultivated fallow (PL). Plots were 20 m x 6 m. WW, FR, RG and PL were ploughed in autumn, TR was ploughed in spring and ST was shallow cultivated in spring and summer. Straw from the previous crop was removed from all plots except FR and ST to which chopped straw was returned. All plots except WW and ST were topped as necessary during spring and summer. After the set-aside treatment year, plots were ploughed ready for the first of the two test winter wheat crops.

On three occasions per year, November, March and August, soil samples were taken at 0-90 cm (in 30 cm depths) and plant samples collected and analyzed for inorganic N and total N respectively. Owing to dry conditions on Site 3 in November 1990 the soil sampling was postponed to January 1991. In addition, at each site ceramic suction cups (three per plot)were inserted to a depth of 90 cm in selected treatments. They were used to sample soil solution over the winter, which was analysed for nitrate-N and ammonium-N. These results, together with estimates of drainage volume, were used to calculate total N leached.

RESULTS AND DISCUSSION

Rainfall

Two winters were dry and one wet. In the two dry winters 1988-89 and 1990-91 the rainfall (1 Sept - 30 March) was 324 and 285 mm and the overwinter drainage volume 140 and 100 mm respectively. In the wet winter 1989-90 the equivalent rainfall was 429 mm and the overwinter drainage volume 232 mm.

Effect of cultivation on autumn mineralisation

The amount of N released by autumn mineralisation can be approximately measured by the sum of plant N and soil inorganic N at the November sampling (Table 1). No N was leached during the autumn in any year. In addition the soil nitrate content will indicate the quantity of readily leachable N. Unexpectedly, at no site did ploughing significantly increase autumn mineralisation and only at site 3 was the soil nitrate content significantly increased (Table 1).

TABLE 1. Effect of cultivation on autumn mineralisation and soil nitrate N in November (1988-91)

Site	Set-aside year	Autumn mineralisation[1] (kg N per ha)		Soil Nitrate (kg NO_3-N per ha)	
		Ploughed	Non-ploughed	Ploughed	Non-ploughed
1	1988-89	73	63	42	28
2	1989-90	104	124	66	84
3	1990-91	109	99	83*	57*

* significantly different at P = 0.05.
[1] calculated as the sum of Plant N + soil mineral N.

Crop N uptake

During autumn, forage rape and the winter stubbles assimilated N most effectively. Uptake by ryegrass was intermediate while wheat, which was sown later, showed the least assimilation. Overwinter, ryegrass showed the greatest N uptake. Forage rape and wheat took up equal, smaller amounts and the uptake of the winter stubbles was small. (Table 2).

TABLE 2. N uptake during different periods by different crops. Mean of 1988-91 (kg N per ha).

	Winter stubbles (ST, TO, TR)	Forage Rape	Ryegrass	Winter Wheat
Sowing to November	20	21	14	7
Nov to March	5	13	21	14

<u>Effect of set-aside treatment on N leaching loss</u>

Overwinter loss (or gain) of soil N was estimated in two ways. Firstly by measuring the difference in soil inorganic N content in November and March and secondly by the direct measurement of soil water samples collected by ceramic suction cups. Results from the soil sampling method are presented below (Table 3):

TABLE 3. Soil Mineral N (kg N/ha) in November and March (1988-91)

Site	Year	Month	PL	ST	TO	TR	FR	RG	WW	SED
1	1988	Nov	76	51	59	57	51	71	75	8.6
	1989	Mar	89	42	41	39	28	32	43	7.9
2	1989	Nov	108	86	103	128	72	67	101	17.8
	1990	Mar	40	35	34	35	24	26	37	6.4
3	1991	Jan	103	60	61	79	95	88	92	21.8
	1991	Mar	106	51	74	50	61	46	52	14.4

Note: Soil mineral N is the mean of nitrate-N and ammonium-N.

At Site 1 (1988-89) no differences were recorded between treatments in November or March except that in March the ploughed fallow (PL) contained considerably more soil N than the other treatments. At Site 2 (1989-90) during the wet winter levels were similar on all treatments but tended to be lower under FR and RG in both November and March, presumably because there was more plant N uptake on these treatments especially in March. At Site 3 (1991) amounts of soil N were similar on all treatments in January and March, but PL tended to have more soil N in March.

Results from the ceramic suction cup sampling method are presented in Table 4:

TABLE 4. Leached nitrate-N sampled by ceramic suction cup (kg NO_3-N per ha)

Site	Year	PL	TO	FR	RG	WW	SED
1	1988-89	-	4	2	6	10	3.1
2	1989-90	-	22	39	42	52	13.9
3	1990-91	79	21	-	50	52	8.4

Ceramic cup results showed considerable site and treatment variation and hence had high SEDs. In Site 1 the dry conditions and small amount of autumn mineralised N were well reflected by the small estimate of leached N. In Sites 2 and 3 estimated losses were similar between treatments and were least from undisturbed soil.

The two methods are complementary and are not directly comparable. Ploughed fallow (not permitted under the Set-aside Scheme) tended to have high levels of soil N and when measured in 1990-91 lost more nitrate-N by leaching. Significant differences in levels of soil inorganic N between the other land treatments were not recorded but during the wet winter (1989-90), when forage rape and ryegrass took up most N, the associated soil inorganic N levels tended to be lower at the end of the winter. Leaching under autum-sown ryegrass was almost as great as under winter wheat in 1989-90 and 1990-91. Natural regeneration was surprisingly effective at decreasing leaching compared to winter wheat.

EFFECT OF THE CUTTING MANAGEMENT OF NATURALLY REGENERATED SET-ASIDE LAND ON THE MINERAL NITROGEN CONTENT IN THE SOIL PROFILE

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ABSTRACT

The effect of cutting management of naturally regenerated set-aside land on the mineral nitrogen content in the soil profile was investigated in three fields. The data suggested that the timing or frequency of cutting the naturally regenerated plant cover or whether the cuttings were removed or left to decay had no effect on the level of mineral nitrogen in the soil.

INTRODUCTION

Of the large number of farmers in NE Scotland who took up the set-aside option, a significant percentage allowed the land to regenerate naturally from cereal stubble, without introducing any sown species. This paper reports interim contents of mineral nitrogen in the soil under different cutting regimes of naturally regenerated set-aside from the most northerly experimental site at Aldroughty Farm, Elgin. Further details of the farm are given by Ford *et al.* (1992, this Symposium).

MATERIALS AND METHODS

Sites

Three contrasting sites at Aldroughty Farm, (National Grid reference NJ1862) near Elgin were chosen. Two of them had soils developed from fluvioglacial sands and gravels and the third soil, heavier textured, was derived from alluvium.

The farm is surrounded by woodland of varying character supporting a diversity of plant and bird species. The experimental treatments based on different cutting regimes, were designed to encourage the spread and assist in the measurement of naturally regenerated plants, whilst simultaneously monitoring soil nitrogen and pH at three depths in the profile.

Treatments

Treatments at each of the three Aldroughty sites consisted of different cutting regimes of plants naturally regenerated from the stubble of barley. In field 10 (alluvium) the treatments comprised three randomised blocks of three main plot cutting managements: early cut (June); late cut (September) and cut twice (June and September). Each main plot was split into two vegetation managements: vegetation removed and vegetation left. Cutting in June or September, and with vegetation either removed or left were repeated with 6 replicates at the loamy sand site (field 14), with an uncut "control". In field 17 (loamy sand) four treatments were randomised in five blocks. The treatments were uncut, early cut (June), late cut (September), and cut twice (June and September).

Soil and plant sampling and analysis

Concentrations of nitrate-N and ammonium-N in soil cores taken from depths of 0-15, 15-30 and 30-45 cm in December 1990 and November 1991 were determined.

10g sieved, moist soil (< 6.4 mm) were shaken with 50 ml 1 M potassium chloride solution for 2 h in an end-over-end shaker and the extract filtered through No. 40 Whatman filter paper. The filter papers were washed with 25 ml 0.25 M potassium chloride solution to remove traces of ammonium (Qasim and Flowers, 1989) prior to filtering the extract. The nitrate-N in the soil extract was reduced to nitrite by passing over a copper-coated, cadmium wire and the concentration of nitrite was determined colorimetrically by a diazotization reaction on an auto analyser (Stainton, 1974).

RESULTS

The quantities of nitrate in the Aldroughty soils to a depth of 45 cm under the treatments where the cut vegetation was either removed or left are given in Table 1.

TABLE 1. Nitrate-N in soil to a depth of 45 cm under different cutting and vegetation managements (kg/ha N)

Cutting	Vegetation management	Field 10 Dec 90	Field 10 Nov 91	Field 14 Dec 90	Field 14 Nov 91
Uncut	-	-	-	18.4	9.2
Early	removed	16.2	15.3	16.4	9.1
Early	left	21.2	21.1	16.6	11.0
Late	removed	14.8	13.7	17.8	11.3
Late	left	12.0	12.6	15.7	9.0
Twice	removed	14.8	13.2	-	-
Twice	left	14.8	14.1	-	-
S.E.D.		5.0	6.0	2.2	1.7

The quantities of nitrate in the Aldroughty soil to a depth of 45 cm under four cutting treatments are given in Table 2. The quantities of ammonium in the Aldroughty soils to a depth of 45 cm under the treatments where the cut vegetation was either removed or left are given in Table 3. The quantities of ammonium in the Aldroughty soil to a depth of 45 cm under four cutting treatments are given in Table 4.

TABLE 2. Nitrate-N in soil to a depth of 45 cm under different cutting managements (kg/ha N)

Cutting management	Field 17 Dec 90	Field 17 Nov 91
Uncut	9.7	13.6
Early	9.9	11.4
Late	9.8	11.1
Twice	11.1	10.0
S.E.D.	1.8	1.9

TABLE 3. Ammonium-N in soil to a depth of 45 cm under different cutting and vegetation managements (kg/ha N)

Cutting	Vegetation management	Field 10 Dec 90	Field 10 Nov 91	Field 14 Dec 90	Field 14 Nov 91
Uncut	-	-	-	23.1	9.2
Early	removed	17.6	14.7	23.1	9.2
Early	left	22.3	21.7	11.6	11.0
Late	removed	15.7	12.6	14.6	11.3
Late	left	16.2	18.8	15.9	9.0
Twice	removed	19.5	18.1	-	-
Twice	left	20.0	12.2	-	-
S.E.D.		4.84	4.40	4.33	1.70

TABLE 4. Ammonium-N in soil to a depth of 45 cm under different cutting managements (kg/ha N).

Cutting management	Field 17 Dec 90	Field 17 Nov 91
Uncut	15.6	32.4
Early	19.4	28.1
Late	15.9	20.6
Twice	17.1	39.1
S.E.D.	1.94	12.5

DISCUSSION

At Aldroughty the effect of cutting management of naturally regenerated set-aside land on the potential for leaching of nitrate was compared in three trials. In Table 1 there were no significant differences between treatments in either field on the quantity of nitrate in the soil. There was a trend towards less nitrate in field 10 where the vegetation was cut in September. Although this trend was repeated in 1991, the differences were not statistically significant, nor were the same trends repeated in fields 14 and 17. The outstanding feature in field 14 was the sparse plant cover, probably as a result of the dry soil conditions in the loamy sand, compared with the dense plant cover in the wetter, heavier textured soil in field 10. In field 17 little nitrate was present and there was no significant difference between treatments.

Table 3 shows that there were no significant differences between ammonium N in the soil under the different treatments in either field. In November 1991 there was a trend towards moreammonium in the wetter, heavier textured soil in field 10 than in the drier soil of field 14.

The amounts of ammonium were generally larger but more variable in November 1991 than in 1990. About half the ammonium in the 1991 sampling was found in the top 0-15 cm. As this field does not have a perimeter rabbit fence and rabbit droppings were seen on the plots, it is suspected that ammonium in the top soil has come from rabbit droppings.

The Aldroughty data suggested that the timing or frequency of cutting the naturally regenerated plant cover or whether the cuttings were removed or left to decay had no effect on the level of mineral nitrogen in the soil.

ACKNOWLEDGEMENTS

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3.
Vegetation Development under Set-aside

Session Organisers and Chairmen: NIGEL BOATMAN and NEIL FISHER

MONITORING OF BOTANICAL COMPOSITON OF SET-ASIDE FIELDS IN ENGLAND

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ABSTRACT

A three year programme has been undertaken to monitor the changes in botanical compositon of fields under set-aside. This paper presents an analysis of the first year's results using indices of botanical value and the abundance of notifiable weed species. It concentrates on the effect of the initial method of establishment and compares results from field boundaries and cores. Fields established by natural regeneration have higher botanical value but also a greater abundance of notifiable weed species than those under a green cover crop. Field boundaries are botanically richer than field cores; weed abundances show conflicting results. These results may change with time as subsequent years' data become available for analysis.

INTRODUCTION

Background

A three-year monitoring programme was initiated in 1991 aimed at identifying changes in the botanical composition of fields entered into the five-year set-aside scheme. Only fields managed under the permanent fallow option were included and fields subject to the Countryside Premium Scheme were excluded. This study forms part of a wider environmental monitoring programme being carried out by ADAS on behalf of MAFF. Furthermore, it complements the experimental approach being carried out on ADAS Research Centres to which other papers in this symposium refer (Clarke & Cooper, 1992).

Objectives

The overall objective of the monitoring programme is to identify the changes in botanical composition of fields under set-aside. This is to be achieved by a combination of annual visits to selected fields and samples of fields of differing aged set-aside (see below).

In order to target future set-aside schemes more effectively, the effects on botanical compositon of a range of factors are being investigated. These include historical factors such as last crop type before set-aside, establishment factors such as number of cover crop species sown and subsequent management factors. In addition, a comparison between a 15m "boundary zone" and the "core" of the field has been mad in order to evaluate an "uncropped boundary" option.

The purpose of this paper is to present the interim results from the first year of monitoring. As such, it is not possible to describe actual changes in the botanical composition of individual fields. We shall concentrate instead on a four-part analysis:

1) The effect on the species composition of fields of initial establishment method; natural regeneration versus a sown green cover crop.

2) The effect on notifiable weeds of initial establishment method.

3) The difference in species composition between the boundary zone and the core of the field.

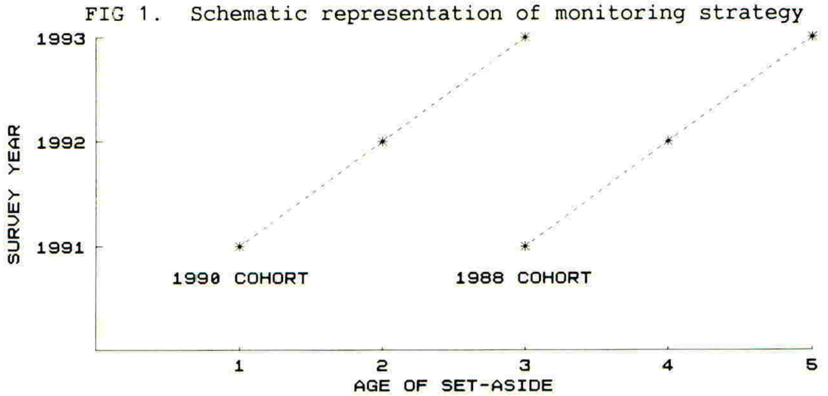
4) The difference in abundance of notifiable weeds between the boundary zone and the core.

METHODS

Monitoring strategy

Fields have been entering the scheme anually since its inception in 1988. Consequently, in the summer of 1991, three cohorts were available representing fields which had been under set-aside for one, two and three years. It was decided to concentrate on the 1988 and 1990 cohorts only, but to resurvey them annually for three years. In this way a direct estimate of change within fields can be made, with the two "parrallel" cohorts spanning a five-year period as shown in Fig 1.

FIG 1. Schematic representation of monitoring strategy



The sampling frame comprised farms containing whole-field, permanent-fallow set-aside. From this a 15% proportional stratified random sample was drawn resulting in 276 farms. The stratification was two-way, based firstly on year of entry (cohort) and secondly, on MAFF region. The latter ensured a representitive geographical spread of sites. This breakdown is shown in Table 1.

Fieldwork was carried out between mid-July and early September. Within each of the selected farms, the most northerly set-aside field was chosen. This provided a practical, objective method of locating fields within a more manageable sampling frame.

TABLE 1. Numbers of sites surveyed in each cohort and by MAFF Region

Cohort	East	Midlands & West	North	S East	S West	TOTAL
1988	37	26	22	52	32	169
1990	36	12	7	30	22	107
TOTAL	73	38	29	82	54	276

The field was divided into the boundary zone (a 15m wide strip running around the edge of the field) and the core. Thirty 50 x 50 cm quadrats were independantly, randomly located in each of these zones. Within each quadrat the rooted presence of all species was recorded. In addition, the dominant species (in terms of leaf cover) was recorded for each quadrat. Thus within each zone a rooted frequency count, as well as a dominance count, out of 30 was obtained for each species. These data have also been aggregated to give counts out of 60 for the whole field.

Data structure and analysis

Three indices of botanical composition of the field have been derived from the raw species data. These indices represent a measure of the botanical value of fields and are defined in Table 2.

TABLE 2. Indices of botanical composition

INDEX	DEFINITION
Species richness	Total number of species recorded per field/zone
Diversity index	Average number of species per quadrat in field/ zone
Dominance index	Number of species in field/zone achieving dominance in at least one quadrat

The five notifiable weed species are *Cirsium arvensis, Cirsium vulgare, Rumex crispus, Rumex obtusifolius* and *Senecio jacobaea*. It is considered that these species represent an adverse measure of the effects of set-aside. Quantitative data on these species consists simply of their frequency counts per zone or field.

Exploratory analysis of these response variables showed that the three botanical indices closely approximated a normal distribution. However, as expected, the five species counts were highly right-skewed, so all subsequent analyses of these data were preceded by an angular transformation.

Multi-way analysis-of-variance models were used, incorporating the two strata (region and cohort) as fixed factors. Initial establishment type was incorporated as a third random factor for the first two analyses. For the latter analyses, the difference between boundary and core was used as the response variable in two-way ANOVA.

RESULTS

A total of 405 species (or species-groupings) were recorded during the first year's survey. Apart from bryophytes, the five most frequently occuring species were, in decending order, *Agrostis* spp., *Elymus repens, Cirsium arvense, Lolium perenne* and *Sonchus asper*. All five were found in more than 200 of the 276 field surveyed. Of the 405 species, 63 were monocotoledons (51 grass spp./spp. groups, 6 *Carex* spp. and 6 *Juncus* spp.).

The effects of initial establishment type

The three graphs in Fig 2 show the difference in botanical composition indices between a sown green cover crop (GC) and natural regeneration (NR). Species richness is significantly higher under natural regeneration ($F_{1,240}$ = 20.0, $P < 0.001$). Similarly, the number of species achieving dominance in a field was significantly higher under natural regeneration ($F_{1,240}$ = 30.6, $P < 0.001$). This result is to be expected as under a green cover crop, sown species will dominate in the short term.

In contrast though, species diversity did not differ between these two establishment options. This may have been influenced by the number of species in the seed-mixes sown. This would tend to result in a small scale diversity which is recorded most sensitively by this method.

FIG 2. The effect of initial establishment type on botanical composition

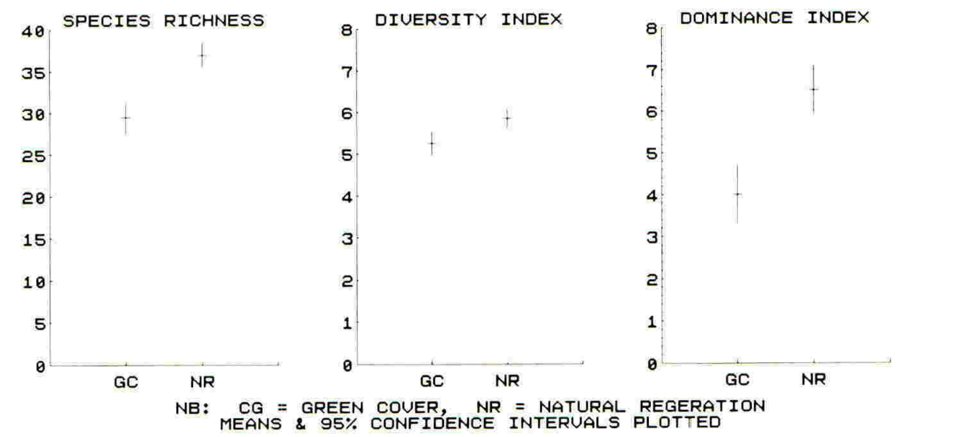
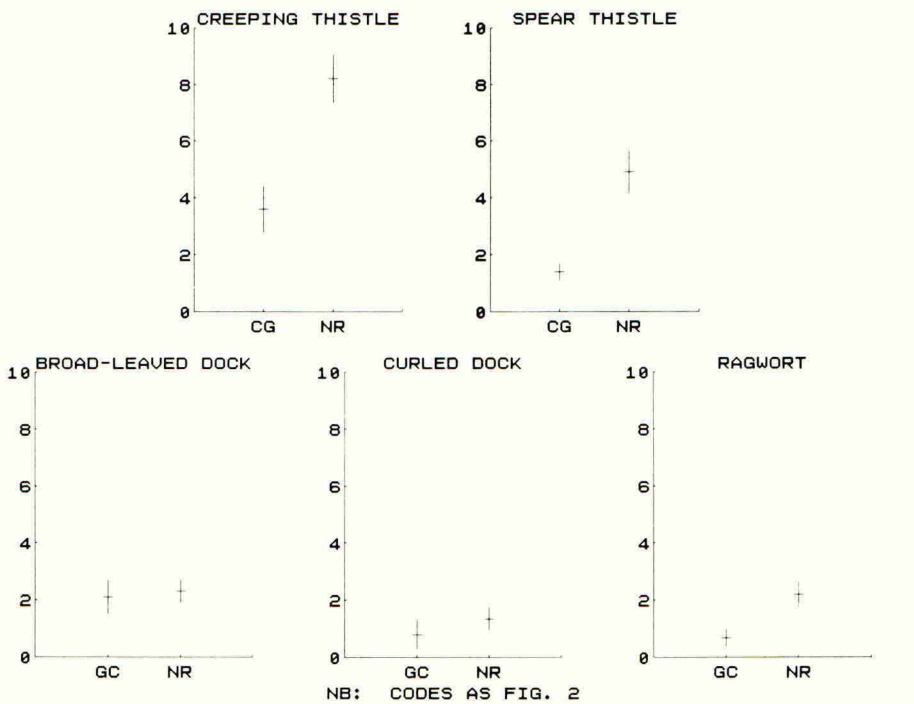


Fig 3 shows similar graphs for abundance of the five weed species. It is clear that the two thistle species are far more abundant in set-aside fields than the other three; creeping thistle attained an average frequency count of 6.6 out of 60 (11%), whilst at the other extreme, curled dock averaged a count of only 1.2 (2%). It should be pointed out, however, that none of these frequencies can be considered to be high.

Only the two thistle species show significantly higher numbers under natural regeneration. This is especially evident for spear thistle with over three times the abundance ($F_{1,240}$ = 13.6, $P < 0.001$). Although the graph for ragwort appears to show a significant difference, it should be

FIG 3. The effect of initial establishment type on weed abundance



emphasised that due to the serious skewness of these data, standard error bars and not confidence limits have been plotted. Finally, it is of interest that neither species of dock appeared to be influenced by the initial establishment type.

Comparisons between field boundary and field core

Every field was divided into core and boundary zones, each containing 30 quadrats, as described in the methods section above. In this way, paired estimates of response variables were provided for each field. To incorporate these paired data into a two-way ANOVA model, the core data were subtracted from the boundary data to give an estimate of difference for each response variable. Thus for species richness, the total number of species recorded in the core of the field was subtracted from the number of species in the boundary. A resultant positive value for this index indicates higher species richness in the boundary, whilst a negative value represents a higher species richness in the core.

Table 3a shows mean values for the differences in the three botanical compositon indices between boundary and core. Again species richness and the dominance index show highly significant differences, with higher scores in the boundary.

TABLE 3. Comparisons between field boundary and field core

	Boundary - Core	Significance
a) Botanical indices		
Species richness	4.20	P < 0.001
Diversity Index	0.04	NS
Dominance Index	0.66	P < 0.001
b) Weed species		
creeping thistle	0.98	P < 0.001
spear thistle	-0.31	NS
curled dock	-0.94	P < 0.01
broad-leaved dock	0.33	NS
ragwort	-0.77	P < 0.01

Table 3b summarises the results for the five notifiable weed species. Only three of these show significant differences. Creeping thistle has a greater abundance in the boundary, whilst curled dock and ragwort are more abundant in the core of the field.

CONCLUSIONS

The analysis of the first year's data from this monitoring programme gives indications of the effects of two factors; the nature of the initial establishment and the different results in the boundary compared with the core of the field.

Botanical composition indices are higher under natural regeneration, suggesting that a higher ecological value can be obtained with this establishment type. However, the weed problem is also greater, although only manifest by the two thistle species. The 15m boundary zone has higher average botanical value than the field core, suggesting that a boundary-only set-aside option may be ecologically valuable. There is no clear evidence that weed species are a greater problem in this zone.

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A BOTANICAL SURVEY OF SET-ASIDE LAND IN SCOTLAND

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ABSTRACT

A reconnaissance survey in the summer of 1991 covered 193 fields of which 80 had been sown with a cover. A more detailed quadrat survey was made of 43 unsown fields and 11 sown fields. In both data sets, the most frequently recorded species in unsown fields were *Trifolium repens* and *Ranunculus repens*. The sown fields had much lower frequency and ground cover of broad-leaved species. Very few annual weeds or volunteer crops were present except in the 6 fields which were in their first year of set-aside. *Poa annua* was present in most unsown fields but the cover by perennial grasses was variable, averaging 37% in total. The survey data were consistent with the succession seen in the trial on an old arable site near Edinburgh where annual weeds and volunteer crops in the first year gave way to biennial or perennial broad-leaved species in later years. It is considered likely that perennial grasses will eventually predominate.

INTRODUCTION

The public has an interest in the set-aside scheme because of its effect on the scenic quality of the countryside and for its possible benefits in creating wildlife habitats. Because of this, the Scottish Office Agriculture and Fisheries Department financed SAC to undertake surveys of set-aside land in Scotland with a view firstly to describing what vegetation has developed and secondly to analyse the site and management factors determining the type of vegetation. This work has been closely integrated with more experimental approaches described by Fisher and Davies (1990, 91) and by Ford *et al*. in this volume. Both parts are ongoing and the purpose of this paper is to give an interim description of the botanical composition of the set-aside areas surveyed during 1991 and to report on preliminary attempts to analyse the factors which might have contributed to its development.

METHODS

The approach used for sites in Fife and Tayside was to visit farms known to have set-aside and to walk all fields on each farm. Farmers were asked to indicate the cropping history, the year of entry into set-aside and whether or not any cover was sown for each field. A rapid assessment was made for each field of the five most important species and their approximate ground cover and all other species seen were listed. Subsequently two fields on each farm (in most cases) were chosen for detailed survey on the basis of having the vegetation most typical of that farm. For the detailed survey, a 0.5 x 0.5 metre quadrat was placed on the ground at twenty locations in a W-shaped transect of the midfield and estimates made of the ground cover by each species seen in the quadrat. A soil sample was taken for analysis. For sites in Grampian, only detailed quadrat surveys were done.

Various analytical techniques were applied to the data but the most useful for the purpose of this paper was to accumulate frequencies or ground covers for each species over all fields and then to rank the species according to frequency or overall ground cover. The latter is a function of both the number of fields within which the species was recorded and its importance within those fields. Subsets of fields were isolated and ranked depending on criteria set independently of the vegetation data such as sown or unsown, length of time in set-aside or soil chemical analysis. Differences in field numbers in which each species was recorded were tested by the chi-squared test.

RESULTS

Reconnaissance survey of fields in Tayside and Fife

Of 193 fields visited, 80 were claimed to have been sown with some form of seed mixture including one or more of *Lolium perenne*, *Trifolium repens*, *T. pratense* and *Festuca rubra*. The average number of species listed for these sown fields was 11.9 (range 4-30, SD= 7.03). For 113 unsown fields, the average number of species was 22.9 (range 7-62, SD= 10.62). In the unsown fields, a total of 189 species were listed and the most frequent are shown in table 1 which also shows volunteer crops and woody species.

The low-growing, creeping, broad-leaved *T. repens* and *R. repens* were the most frequent species recorded in unsown fields and more common than the most frequent grasses, *P. annua* and *H. lanatus*. Injurious weeds such as *C. vulgare*, *R. obtusifolius*, *C. arvense*, and *S. jacobaea* were common as was *E. repens*. All of the likely volunteer crops were seen but none in high numbers of fields.

There was very little encroachment of woody species on these fields but *U. europaeus* was the most common and of importance on one field. None of the 189 species could be called uncommon except *Ornithopus purpusillus* which is "rare in the north" (Clapham *et al.*, 1981). There were about 16 species which are usually found in wet areas, woods or field margins rather than in farmland.

Detailed survey of fields in Tayside, Fife and Grampian

Over the 43 unsown set-aside fields in the detailed survey, *R. repens* was the species with greatest overall ground cover, followed by *T. repens* (Table 2). *A. capillaris* was the most abundant grass, closely followed by *P. annua* and then by six perennial grass species, including *E. repens*. The total cover by perennial grasses averaged about 37% but was less than 30%

in 43% of unsown fields. The most common tall-growing broad-leaved species were the willowherbs (especially *C. angustifolium*), thistles (especially *C. vulgare*), docks (especially *R. acetosella*) and ragwort (*S. jacobaea*).

TABLE 1. Most frequent and selected other species recorded in the reconnaissance survey of 113 unsown set-aside fields in Tayside and Fife, summer 1991.

	No of fields	No in top 5		No of fields
Most frequent species:			Volunteer crops:	
Trifolium repens	99	60	Oilseed rape	11
Ranunculus repens	95	70	Wheat	8
Cirsium vulgare	91	36	Potatoes	7
Poa annua	88	32	Barley	3
Cerastium fontanum	83	5	Oats	1
Holcus lanatus	81	42		
Rumex obtusifolius	77	7	Woody species:	
Cirsium arvense	64	5		
Epilobium obscurum	62	3	Ulex europaeus	5
Poa trivialis	62	27	Acer pseudoplatanus	3
Dactylis glomerata	60	23	Alnus glutinosa	2
Senecio jacobaea	60	14	Fraxinus excelsior	2
Myosotis arvensis	57	2	Quercus agg.	2
Agrostis capillaris	55	18	Rubus fruticosus	2
Chamerion angustifolium	47	6	Calluna vulgaris	1
Sagina procumbens	45	2	Fagus sylvatica	1
Veronica serpyllifolia	45	0	Ulmus procera	1
Sonchus asper	44	2		
Elymus repens	41	15		
Myosotis discolor	40	1		
Phleum pratense	40	8		
Viola arvensis	40	0		

In the 11 fields with a sown cover, the sown species, *T. repens*, *L. perenne*, *F. rubra* and *Phleum pratense* were obviously much more important. Most other species had much reduced mean ground covers compared with unsown fields. *A. capillaris*, *P. annua*, *H. lanatus*, *C. fontanum*, *E. obscurum* and *R. acetosella* were recorded in signiciantly fewer sown fields than expected from their frequency in unsown fields.

Effect of length of time under set-aside

The majority of the set-asides in the sample were last cropped in 1988 and the differences in Table 3, given the very small samples in 1989 and 1990 entry years, are confounded by site effects. The only statistically significant departures from "expected" in field numbers were for *A. stolonifera* and *T. campestris* which appear to have been particularly common in two-year old set-asides and for the annuals: *T. aestivum*, *S. media*, *P.*

persicaria and *M. matricarioides* which were more or less confined to the one year old fields.

TABLE 2. The twenty species with greatest ground cover in 43 unsown set-aside fields and 11 sown fields in Scotland, detailed survey 1991.

	Unsown			Sown		
Species name	Rank	No fields	Cover %	Rank	No fields	Cover %
Ranunculus repens	1	38	15.7	8	4	0.5
Trifolium repens	2	36	11.7	1	11	47.6
Agrostis capillaris	3	30	10.4	-	-	-
Poa annua	4	33	8.9	18	2	0.1
Holcus lanatus	5	36	8.1	20	1	0.1
Elymus repens	6	29	5.1	6	3	0.7
Lolium perenne	7	17	2.6	2	11	22.5
Dactylis glomerata	8	25	2.5	16	3	0.2
Agrostis stolonifera	9	10	2.4	9	1	0.3
Poa trivialis	10	19	1.7	15	2	0.2
Chamerion angus.	11	15	1.7	27	1	0.1
Phleum pratense	12	21	1.7	4	5	1.9
Cerastium fontanum	13	25	1.6	26	1	0.1
Epilobium obscurum	14	17	1.5	-	-	-
Cirsium vulgare	15	28	1.2	5	5	1.0
Bellis perennis	16	16	1.1	24	1	0.1
Alopecurus genic.	17	12	1.1	32	1	0.0
Rumex acetosella	18	19	1.0	-	-	-
Senecio jacobaea	19	17	1.0	10	1	0.3
Poa pratensis	20	7	0.8	-	-	-
Festuca rubra	57	5	0.1	3	7	16.9
Cirsium arvense	23	18	0.6	7	3	0.6
Tussilago farfara	74	3	0.1	11	1	0.3
Solanum tuberosum	130	1	<0.1	12	1	0.3
Trifolium pratense	58	9	0.1	13	2	0.2
Rumex obtusifolius	36	15	0.4	14	3	0.2
Fumaria officinalis	86	3	<0.1	17	1	0.1
Trifolium dubium	41	7	0.3	19	2	0.1

DISCUSSION

The results from these surveys agree with information from the designed trials (Fisher and Davies, 1991) that sowing a grass or grass-legume mixture drastically reduces the botanical diversity and the importance of broad-leaved "weeds". From the point of view of the control of injurious weeds and the return of the land to subsequent cropping, there can be no doubt that sown covers are a desirable management for land set-aside for longer than two years. For wildlife and the enhancement of biological diversity they may be less desirable.

Few would have predicted that *R. repens* would be the dominant species in unsown set-asides at this point in their vegetational development. It is assumed to have spread vegetatively from a few germinating seeds surviving since the land was last in pasture. Chancellor (1985) found *Ranunculus spp.* (possibly mostly *R. bulbosus*) germinating in an arable field in southern England up to 13 years after it had been ploughed from grass. *T. repens* has also probably survived since our set-aside fields were in grass, as it did for up to 21 years in Chancellor's field. Both species give effective ground cover and are easy to mow.

TABLE 3. Differences with age of set-aside fields in the ranks and frequencies of species up to 15th ranking, unsown fields in the detailed survey, summer 1991.

Year of entry:	1988		1989		1990	
Number of fields:	29		5		6	
Number of species:	133		68		71	
	Rank	No of fields	Rank	No of fields	Rank	No of fields
Ranunculus repens	1	27	1	4	9	4
Trifolium repens	2	25	2	4	6	4
Agrostis capillaris	3	22	4	5	2	3
Holcus lanatus	4	27	6	5	5	3
Poa annua	5	21	5	5	1	5
Lolium perenne	6	10	24	2	19	3
Elymus repens	7	17	3	5	3	6
Dactylis glomerata	8	18	19	3	14	3
Poa trivialis	9	16		0	21	1
Cerastium fontanum	10	19	20	3	60	1
Chamerion angust.	11	11	7	1	29	2
Phleum pratense	12	15	8	2	40	2
Epilobium obscurum	13	11	9	3	52	1
Alopecurus geniculatus	14	10	18	2		0
Bellis perennis	15	13		0	13	3
Rumex acetosella	17	15	13	3	36	1
Agrostis stolonifera	19	5	10	10	4	2
Cirsium vulgare	20	16	14	5	31	4
Holcus mollis	21	8	59	1	11	2
Crepis capillaris	22	7	11	2		0
Viola tricolor	33	7	12	3		0
Stellaria media	65	3		0	8	3
Matricaria matricar.	73	2	29	1	12	4
Trifolium campestre		0	15	2		0
Triticum aestivum		0		0	7	4
Polygonum persicaria		0	47	1	10	2

Taken in total, the perennial grasses represent a significant fraction of the vegetation on these set asides. They include the creeping *E. repens* and *A. stolonifera* which are certainly potential weeds of arable cropping and *E. repens* in particular was present in a high proportion of the fields visited. Of some amenity significance are the tall-growing thistles (*Cirsium spp.*), docks (*Rumex spp.*), willowherbs (*C. angustifolium* and *Epilobium spp.*) and ragwort (*S. jacobaea*). With most of the fields in their third year of set-aside, the typical annual weeds of arable crops had virtually disappeared. Volunteer crops were also of very minor significance. Also uncommon were woody species but one field had worrying quantities of *Ulex europaea*. The preponderance of *A. pseudoplatanus* and absence of birch or pine provides little encouragement to those who see set-aside as a possible means of regenerating native Scottish woodlands. However, no attempt was made to exclude deer and rabbits from these fields.

Although our data are sparse for fields less than three years in set-aside, they are consistent with the succession seen in the Hill Field trial on an old arable site near Edinburgh (Fisher and Davies, 1991). On such sites, the seedbank populations of perennial grasses are very low and the first year tends to be dominated by *Poa annua* and a selection of several annual weeds or volunteers such as *C. bursa-pastoris*, *M. matricarioides*, *Polygonum spp.*, *S. media*, barley, wheat or oilseed rape. By the second year, biennial or perennial dicots become much more important: *R. repens* or *T. repens*, otherwise one of the tall-growing pasture weeds. *E. repens*, if present, is also likely to increase. Ultimately, under the light rabbit and deer grazing and occasional cutting regimes of typical set-aside fields in Scotland, we would expect one or more perennial grasses to dominate: typically *A. capillaris*, *D. glomerata* or *Holcus spp.*

This succession implies that the seedbank, reflecting previous weed management practice, is the dominant influence on early vegetational development. We have not found much relationship with soil factors such as P or K status or pH. A further conclusion is that if an attractive vegetation or wildlife habitat, whether grassy or woody, is wanted on redundant arable land, within a reasonable timescale, it probably has to be sown or planted with the chosen species.

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THE NATURAL REGENERATION OF VEGETATION UNDER SET-ASIDE IN SOUTHERN ENGLAND.

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ABSTRACT.

The naturally regenerating vegetation of set-aside fields was surveyed on 21 farms in the south of England between 1989 and 1991. The proportion of annual species declined as the vegetation developed, while the proportion of perennial species increased. The presence of adjacent semi-natural habitats influenced which species occurred, while soil characteristics had a lesser effect. It is concluded that in some situations set-aside can introduce valuable habitat diversity into the countryside.

INTRODUCTION.

The set-aside scheme was designed primarily to reduce surplus cereal production, and not for its benefits to wildlife (MAFF, 1988). Considerable interest has however been shown towards the potential for wildlife of set-aside arable land. In order to provide some basic information on the development of vegetation following setting-aside, and to see whether communities of conservation value might be expected to develop, a survey of naturally regenerating vegetation on set-aside land was carried out during the summers of 1989, 1990 and 1991.

METHODS.

Set-aside fields in which the vegetation had been allowed to develop naturally following the harvest of the previous crop were surveyed during the summers of 1989, 1990 and 1991. 58 fields on 21 farms in the south and east of England from Dorset to Norfolk were included.

A complete list of vascular plant species was recorded from each field, with abundance estimates on a "DAFOR" scale (D= dominant, A=abundant, F=frequent, O=occasional, R=rare). These results were subjected to canonical correspondence analysis (ter Braak, 1987). Number of years since the harvest of the last crop, simple soil characteristics, and the presence of adjacent semi-natural habitats were considered as environmental variables, with the 21 farms as covariables. The effects of the individual environmental variables were investigated in further analyses using the other variables as additional covariables. The number of species per field and the proportions of three classes of species : 1. seed-bank forming species and others which may have been present as weeds before setting-aside, 2. species characteristic of disturbed habitats but not of arable fields, 3. species characteristic of more stable habitats; were analysed by analysis of variance with respect to the number of years since the harvest of the previous crop.

In all but four of these fields, the percentage cover of each vascular plant species, unvegetated ground and bryophytes was also recorded in 20 randomly placed $0.25m^2$ quadrats. Canonical correspondence analysis was carried out on this data, although the farms were found to have no significant effect, and were therefore not used as covariables. The percentage covers of six grass species, unvegetated ground and plant litter were all analysed individually by analysis of variance with respect to the number of years since the harvest of the last crop.

RESULTS.

Vegetation cover developed rapidly on the set-aside fields (Table 1). In the first year (approximately 10 months after harvest of the preceding crop), a mean of 30% of the field area was unvegetated and by the end of the second year, this had decreased to about 5%. Plant litter increased between the first and second years, but decreased again in the third.

TABLE 1. Percentage of bare ground and plant litter (from quadrat data, means back-transformed from arcsin transformed data); total number of species (from whole-field data, means back-transformed from square-root transformed data); numbers of species of three classes as proportions of the total number of species (from whole-field data, means back-transformed from arcsin transformed ratios). Upper and lower 95% confidence limits in parentheses. Significance levels: *** P<0.001, ** P<0.01, * P<0.05.

	Years since last crop was harvested 1	2	3	
Bare ground %	**30.12** (37.23 23.47)	**4.98** (7.35 3.05)	**5.15** (7.56 3.19)	***
Litter %	**1.02** (2.49 0.19)	**20.03** (26.02 14.65)	**12.81** (16.73 9.34)	***
Total no. of species	**59.14** (62.93 54.27)	**57.11** (61.44 52.94)	**54.41** (59.7 49.36)	
Species with persistent seed-banks	**0.46** (0.48 0.43)	**0.34** (0.36 0.31)	**0.28** (0.31 0.24)	***
Species characteristic of disturbed habitats	**0.25** (0.27 0.24)	**0.31** (0.34 0.29)	**0.30** (0.32 0.27)	*
Species characteristic of stable habitats	**0.23** (0.26 0.21)	**0.29** (0.32 0.26)	**0.36** (0.40 0.32)	***

The total number of species present remained remarkably stable from year to year although varying considerably between sites. This apparent stability concealed the considerable changes occurring within the composition of the vegetation. In the first year, "arable weeds" from the seedbank were most frequent. The proportion of these species declined with time, so that by the third year, perennial species had come to be the most frequent, although "arable weed" and "ruderal" species were still numerous.

The contributions of seven grass species to the vegetation were examined in greater detail (Table 2). The percentage covers of *Agrostis stolonifera, Arrhenatherum elatius* and *Alopecurus myosuroides* did not differ significantly between years. The amounts of *Bromus sterilis, Poa trivialis* and *Elymus repens* all increased between the first and third years, while *P. annua* decreased considerably.

TABLE 2. Mean percentage cover of seven grass species with 95% confidence limits (in parentheses) in set-aside fields in three years after the harvest of the last crop. Results back-converted from arcsin transformed results.

	Years since last crop was harvested			
	1	2	3	
Bromus sterilis	**1.23**	**10.44**	**18.45**	***
	(2.88 0.27)	(16.05 5.95)	(29.37 9.62)	
Poa trivialis	**1.23**	**3.07**	**6.71**	*
	(2.68 0.33)	(6.18 1.01)	(11.07 3.38)	
Elymus repens	**0.84**	**5.65**	**7.17**	***
	(1.52 0.36)	(9.61 2.69)	(13.21 2.86)	
Poa annua	**6.81**	**5.29**	**0.2**	***
	(11.96 3.03)	(9.38 2.32)	(0.53 0.03)	

Canonical correspondence analysis (Table 3) showed that the number of years that had elapsed since the harvest of the preceding crop had a highly significant effect on the composition of the vegetation. Only sampling by random quadrats detected the effects of edaphic variables (soil texture, drainage and the presence of chalk and limestone). The only adjacent semi-natural habitat that was found to have a significant effect on the developing vegetation was grassland, and several species characteristic in particular of calcareous grasslands were recorded.

TABLE 3. Canonical correspondence analysis. Monte-Carlo permutation tests.

	Whole field survey	Quadrat survey
Farm	*	N.S.
No. of years since harvest of last crop	**	**
Soil texture	N.S.	**
Impeded drainage	N.S.	*
Chalk/limestone	N.S.	**
Adjacent grassland	**	**

DISCUSSION.

The vegetation of the set-aside arable land underwent a process of rapid change during the first three years of succession. There was a decline of species characteristic of arable habitats, a short-lived increase in species characteristic of disturbed habitats, especially those with wind-dispersed seeds including *Epilobium* spp., *Senecio* spp. and thistles, and an increase in the number of species of more stable habitats. This change in proportion of species with different life-cycles is to be expected in the first years of "old-field" succession (Schmidt, 1988; Gibson & Brown, 1991). The annual grass species *Bromus sterilis* however, increased between years 1 and 3, and in some, but by no means all fields, their centres had become dominated by this species.

Similarities between the fields were as noteworthy as the differences. Thirty eight species (including the grass species *Agrostis stolonifera, Bromus sterilis, Elymus repens* and *Poa trivialis,* one or other of which was the dominant species in most fields) were present in more than 50% of the surveyed fields. All of these are of ubiquitous occurence in southern England (Perring & Walters, 1990). Twenty four of these species are considered by Grime et al (1988) to have "competitive ruderal" and "ruderal" strategies, while only two, the annuals *Veronica arvensis* and *Myosotis arvensis* are considered "stress-tolerating" species. An increase in number of "stress-tolerating" species and a decrease in number of "ruderal" species may be predicted during the course of succession.

In addition to the expected abundance of annual and ruderal species in the first year after the harvest of the preceding crop, a number of perennial species were also recorded. Some of these (e.g. *Acer pseudoplatanus, Fraxinus excelsior* and *Salix capraea*) are woody species with wind-dispersed seeds, probably derived from adjacent hedgerows. In an unmanaged situation, such woody species would eventually come to dominate old fields on all but the most nutrient-poor soils (Schmidt, 1988). Others including *Agrostis stolonifera* and *Glechoma hederacea* (Grime et al, 1988) are known to show considerable invasive ability in recently disturbed sites. In addition however several species normally associated with undisturbed grasslands, including *Bromus erectus, Polygala vulgaris, Pimpinella saxifraga, Lotus corniculatus, Primula veris* and *Carex flacca* also occurred. Such species had become more numerous by the third year, and in most cases were evidently derived from areas of adjacent semi-natural grassland, some of which were very small. These species were usually restricted to a zone of up to 10m wide adjacent to the field boundary, although in a few fields, substantial populations of species such as *Primula veris, Ranunculus bulbosus, Carex nigra* and *Lychnis flos-cuculi* were recorded at considerable distances from the field boundaries, in situations where they were not immediately apparent in adjacent habitats. Seeds of these species may have persisted in the seed-bank since the fields were first ploughed, although neither Graham and Hutchings (1988) or Gibson and Brown (1991) found few seeds of any calcareous grassland "stress-tolerant" species in recently cultivated soils. The two most abundant species recorded by Fisher et al (1992) in a survey of Scottish set-aside fields were the perennials *Ranunculus repens* and *Trifolium repens*. Both of these species can persist as weeds in arable fields, especially where these are relatively poorly drained, and can exhibit very rapid vegetative spread where the level of competition from other species is low.

This survey suggests that where adjacent habitats are present, grassland species can colonise set-aside land readily, albeit with a relatively slow rate of spread. Such habitats are now relatively uncommon in the lowlands of southern England, although relic areas were found next to 18 out of the 58 fields surveyed. It is therefore possible that the setting-aside of arable land may be a useful tool for the restoration of an element of habitat diversity to the countryside. It is known that many examples of species-rich calcareous grassland in England owe their origins to secondary sucession on abandoned arable soil (Gibson & Brown, 1991 b.).

The course of succession is strongly determined by the presence or absence of grazing animals, grazing leading to more rapid colonisation and the maintenance of a species-rich community (Gibson & Brown, 1991 a.; Rodwell, 1992). Current set-aside regulations (MAFF, 1990) permit the grazing of set-aside fields, although the lower grant and the cost of fencing have not been designed to make this option attractive to farmers. In the absence of grazing, it is probable that the vegetation of many set-aside fields will develop into some form of *Arrhenatherum elatius* grassland. Rodwell (1992) describes a number of sub-communities of *A. elatius* grassland, of which some are thought to be particularly characteristic of abandoned arable land on chalky soils. Several of the surveyed fields however contained large areas in which more diverse plant communities appeared to be developing. In view of the impoverished nature of much of our arable farmland for wildlife, it is desirable that the fields in which there has been the best development of semi-natural vegetation during the current set-aside scheme are maintained, and are not lost as a result of changes to the scheme.

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CHANGES IN VEGETATION COMPOSITION AND DISTRIBUTION WITHIN SET-ASIDE LAND

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ABSTRACT

The distribution of flora under set-aside, with respect to distance from the field boundary and the contribution of different sources of origin is discussed using results from an extensive survey of 40 set-aside fields and an intensive study of one field. Perennials and biennials provided most of the cover. Perennial species generally declined with distance from the boundary whilst biennials and annuals increased. A notable exception was the annual Galium aparine which decreased with distance. Data from the intensive study showed three main sources of plant origin. These were, spread by vegetative propagation, e.g., Agrostis stolonifera; an increase in wind-disseminated species including Sonchus and Crepis spp. and a decline in diversity and cover of annuals originating from the seed bank, over the three year study period.

INTRODUCTION

Plants capable of colonising set-aside land may originate from, the seed bank reflecting previous cropping history, adjacent vegetation or wind-disseminated seeds from more distant sources. Consequently, species distributions are likely to differ depending on the origin of the parent plant, subsequent seed dispersal and the length of time that has elapsed following abandonment of arable cropping.

In order to determine the distribution of plants relative to distance from the field boundary and the respective contribution of different sources of seed origin, an extensive survey of set-aside land was carried out together with a more detailed investigation of one specific site.

METHOD

Forty fields under permanent set-aside, in the South and South-East of England, were surveyed for floral composition. The vegetation of all fields surveyed had been allowed to develop naturally following harvest of the previous crop and the fields were managed in accordance with Set-aside guidelines (Anon, 1988). More detailed assessments were carried out on one particular field, located near Basingstoke, Hants., which had been sown to cereals for at least four years preceding set-aside.

General field survey

Vegetation of the 40 sites was evaluated during summer 1991. Seven fields were in year 1 of set-aside and sixteen and seventeen in years 2 and 3, respectively. Four transects were positioned at 10m intervals away from adjacent field edges, in order to minimize distance related effects. Sampling points were located perpendicular to the boundary at 0, 1, 5, 10, 15 and 20m, with the first sample taken within the permanent boundary vegetation. At each sampling point percentage cover of all vegetation, bare ground and litter was recorded within a $0.25m^2$ quadrat. Data was arcsin transformed to improve homogeneity and subjected to analysis of variance.

Intensive field study

Vegetation assessment

Fixed transects were established in spring 1990 to evaluate changes in species composition, distribution and abundance over a three year study period, at one of the field sites surveyed above. Three transects were randomised within each plot (50m long) and replicated three times. The edge of the previously cultivated zone was initially taken as zero, to allow for differences in width of the boundary base, but referred to as 1m hereafter. Sampling points were located at 0, 0.5, 1, 2.25, 3.5, 6, 11, 21 and 41m, perpendicular to the boundary. Percentage cover of all plants and bare ground was recorded, within a $0.09m^2$ quadrat, during mid-May of 1990 - 1992 inclusively.

Soil seed bank

Soil samples were taken to provide baseline information on species diversity and abundance within the seed bank. One transect was located in each plot and the same sampling distances used as above. Eight soil cores, 2.5cm diameter and 20cm depth, were collected from each sample point, except the boundary sample which was taken to a depth of 15cm. Samples were taken in May 1990, placed in half sized seed trays (21cm x 15cm) and transferred to an unheated poly-tunnel. The samples were watered regularly, soil disturbed and trays re-randomised periodically, after emerging seedlings had been identified and removed (Brenchley & Warington, 1930; Roberts, 1981).

RESULTS

General field survey

Transect data from the 40 fields were analysed for individual species. The overall number of species declined with increasing distance from the field boundary, although there was on average a difference of less than two species between 0m, (6.92) and 20m (5.21). However, bare ground increased from 0.83% at 0m to 6.12% at 20m, litter cover followed a similar, though more gradual, increase with distance from the boundary (Table 1).

Forty-eight plant species were recorded in sufficient quantity to permit statistical analysis. Of these 13 declined and 15 increased significantly with distance, the remaining 20 species showed no significant trend in their distribution. From these general patterns, more specific distributions can be identified. Festuca rubra, Urtica dioica, Prunus spinosa, Rubus fruticosus agg. and Heracleum sphondylium declined rapidly with distance from the field edge. Arrhenatherum elatius, Dactylis glomerata and Galium aparine declined more gradually from a maximum in the field boundary, whilst, Agrostis stolonifera declined from a peak at 1m from the field boundary. Both Elymus repens and Holcus lanatus declined with distance, but showed a slight increase at 20m.

Alopecurus myosuroides, Polygonum aviculare and Viola arvensis all showed a steady increase with distance from the field edge. Other species such as Poa annua, Bromus sterilis, Crepis vesicaria and Cirsium vulgare, also showed a significant increase with distance but, peaked at 5, 10, 10 and 15m, respectively (Table 1).

A further 20 species including Convolvulus arvensis, Matricaria perforata, Myosotis arvensis, Cirsium arvense, Poa trivialis and Avena fatua showed no significant trend in their distribution (data not shown).

TABLE 1 Mean percentage cover at six distances from the field boundary. Analysis of variance carried out on log transformed results for species number, and arcsin transformed results for other measures. Means are back-transformed, + = trace presence. Significance of results:- *** P<0.001, ** P<0.01, * P<0.05; D with respect to distance, F between fields.

	Distance (metres)							
	0	1	5	10	15	20	D	F
Litter	5.65	8.23	9.36	9.48	9.13	9.66	*	**
Bare Ground	0.83	3.83	4.51	4.64	5.24	6.12	***	***
Agrostis stolonifera	3.17	11.76	6.46	4.06	4.35	3.79	*	
Arrhenatherum elatius	9.07	2.6	0.12	0.19	0.17	0.18	***	**
Dactylis glomerata	2.93	1.92	0.15	0.02	0.02	0.04	***	
Elymus repens	10.69	8.23	1.43	2.6	3.1	2.76	***	
Festuca rubra	17.30	0.30	0.01	0	0	0	***	
Galium aparine	0.67	0.16	0.05	0.05	0.05	0.01	***	
Glechoma hederacea	0.9	0.24	0	0	0.01	0.01	***	
Heracleum sphondylium	2.44	0.28	0.02	0	0	0	***	
Holcus lanatus	1.58	0.92	0.33	0.08	0.22	0.35	**	*
Alopercurus myosuroides	+	0.61	0.69	1.41	1.71	1.68	***	
Bromus sterilis	1.71	6.07	14.45	15.67	11.76	12.94	***	***
Cirsium vulgare	0.10	0.07	0.42	0.31	0.74	0.50	***	***
Crepis vesicaria	0	+	0.03	0.38	0.29	0.15	***	
Poa annua	0.03	0.31	3.64	3.24	1.84	2.29	***	
Polygonum aviculare	0.07	0.08	0.13	0.45	0.66	0.76	**	
Sonchus oleraceus	0.01	0.09	0.66	0.79	0.81	0.81	***	
Taraxacum spp.	+	0.04	+	0.10	0.10	0.13	*	
Veronica arvensis	0.01	0.19	0.34	0.34	0.45	0.33	**	*
Viola arvensis	0.04	0.05	0.2	0.4	0.9	1.04	***	*
Number of species	6.92	6.41	5.98	5.60	5.51	5.21	***	

Intensive field study

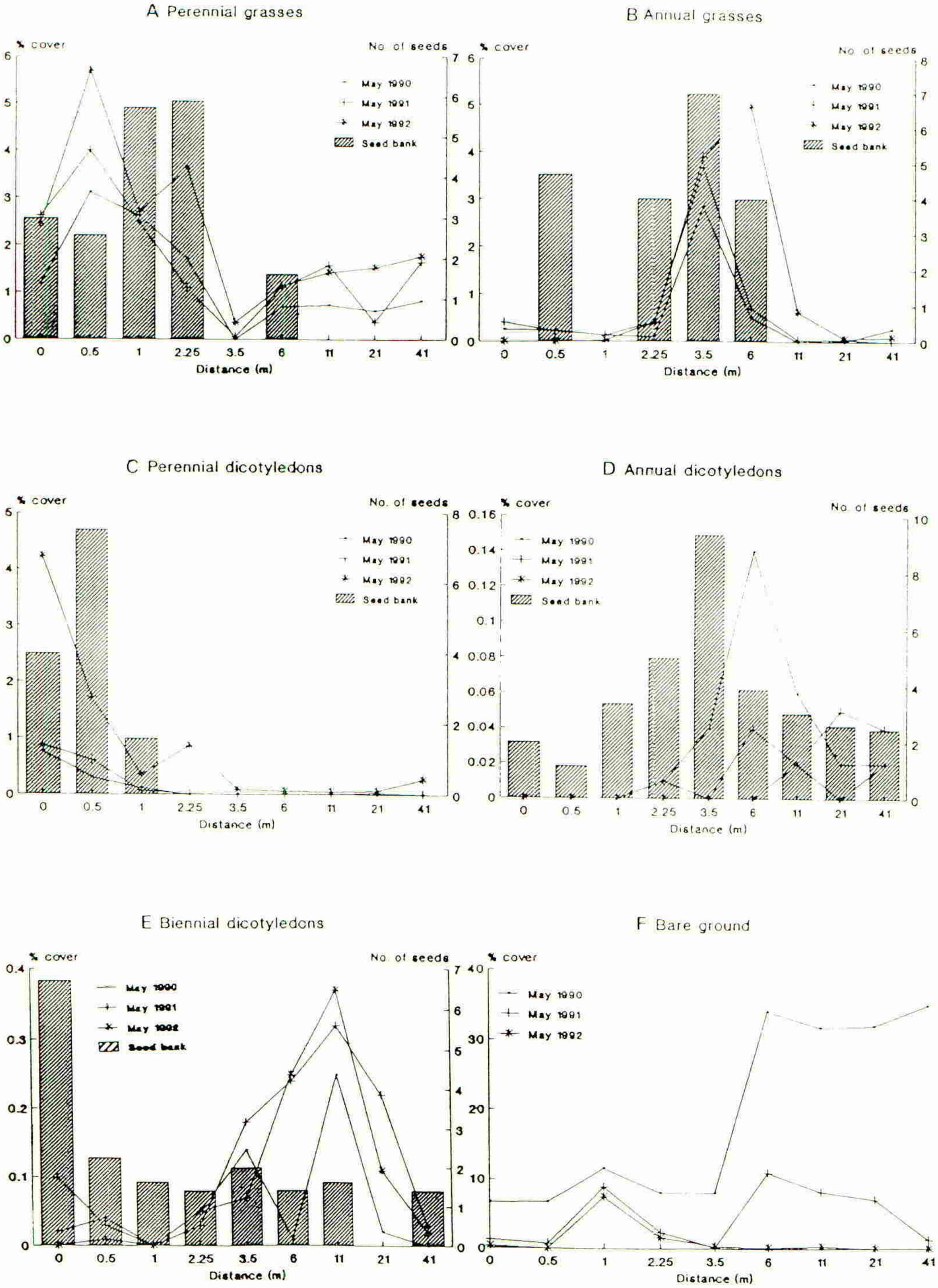
Species were separated into perennial, biennial and annual grasses and dicotyledons, to evaluate any general compositional change that occured over the 3 year study period. Volunteer cereals, Lolium perenne and Poa spp. were excluded from the analysis, the former two because they originated from previous crops and the latter due to difficulty in separating Poa spp. as seedlings.

Vegetation assessment

The distribution patterns of each life-history group was similar from year to year, although there was a shift in the relative percentage cover (Figs 1a-f). Overall, perennial and annual grasses and perennial and biennial dicotyledons increased in cover between years, whilst annual dicots declined. Bare ground decreased rapidly between years and although a peak remained at the interface between permanent vegetation and previously cultivated land (1m), the decline was most pronounced in the field (2.25-41m). This area was colonized mainly by perennial grasses, particularly Agrostis stolonifera, and biennial dicotyledons (Figs 1a,e). Bare ground in the boundary was also exploited by perennials, most notably Arrhenatherum elatius and Festuca rubra.

In general, the distribution of perennial grasses declined from a maximum in the field boundary, with least cover at 3.5m. This trough in perennial cover corresponded with a peak in annual grass cover (Figs 1a,b). When the perennial grasses are considered at

FIGURE 1. Distribution of different life-strategists relative to distance from the field boundary, in Set-aside land.



individual species level it is apparent that species such as F. rubra, A. elatius and D. glomerata declined rapidly from a maximum in the boundary to a distance of 2.25m, whilst E. repens and Agrostis spp. (especially A. stolonifera) were found in relatively high proportions up to 41m. The peak in annual grasses, at 3.5m, was accounted for mainly by Bromus mollis and B. sterilis.

Soil seed bank

Perennials declined exponentially ($p < 0.001$) and biennials linearly ($p < 0.05$) with distance from the boundary. In contrast, annuals increased linearly ($p < 0.001$), although peaking at 3.5m. The annual grasses showed a second smaller peak in the boundary, but it should be noted that only Bromus spp. were recorded in the seed bank.

Seed bank and vegetation cover

Field distribution patterns of the soil seed bank closely resembled those of the vegetation transects, particularly in year 1 (Figs 1a-e). However, the seed bank data showed a higher availability of annuals and biennials in the boundary zone than was reflected in the vegetation assessments, conversely, the perennial seed bank declined whilst the vegetation cover peaked in the boundary. Throughout the three year study period fewer species were found in the seed bank than vegetation transects for all groups except the annuals. The number of grass species in the transects remained the same, except in the third year when Avena fatua was not recorded; biennials declined between years 1-2 and annual dicots declined from 21 to 10 over the 3 year period (Table 2). These discrepancies probably reflect a lack of desirable germination conditions and opportunities for annual and biennial species, together with a reliance on vegetative propagation in perennial grasses which was poorly represented in the seed bank.

TABLE 2. Numbers of species found in the seed bank and vegetation assessments over the 3 year study period. (Figures in parentheses are the number of species found in the seed bank and as plants).

	GRASSES		DICOTYLEDONS			
	PERENNIAL	ANNUAL	PERENNIAL	BIENNIAL	ANNUAL	TOTAL
SEED BANK	4	1	4	3	26	38
TRANSECTS						
1990	6(4)	3(1)	9(3)	8(3)	21(15)	47(26)
1991	6(4)	3(1)	7(2)	5(4)	14(12)	35(23)
1992	6(4)	2(1)	10(3)	5(3)	10(9)	33(20)

DISCUSSION

Data from the survey of 40 fields in one of the first three years to set-aside showed similar general patterns to those observed in the intensive field study. The percentage cover of grasses was much greater than that of the dicotyledons for both data sets. In general, percentage cover of perennial species declined with distance from the boundary, whereas biennial and annuals increased. Such patterns have been observed previously in the context of weed ingress from the field boundary into the field (Marshall, 1985).

Of the species present in sufficient quantity to permit statistical analysis, in the general survey, 13 decreased, 15 increased significantly with distance and 20 showed no significant trends in their distribution. Nine species were largely restricted to the permanent vegetation and to a zone within 5m of this. Other species, notably A. stolonifera and E. repens showed their potential for ingress and declined more gradually. It is notable that although B. sterilis was recorded at all distances it was markedly less prevalent in the field boundary, whilst G. aparine was most abundant in that area and decreased dramatically with distance into the field (Table 1). Field boundaries are often regarded, by the farming community, as a reservoir from which pernicious weeds such as B. sterilis and G. aparine can spread (Boatman & Wilson, 1988). G. aparine is regarded as a nitrophilous species (Mahn, 1984) and therefore may not become a problem on lighter soils where set-aside will result in reduced levels of soil fertility and a consequent decline in the seed bank.

Bare ground in the general survey increased significantly with distance from the boundary, but there was also a significant difference between fields. Data from the primary site showed that there can be a dramatic change in the availability of bare ground between years (Fig 1f), therefore the variation found between fields in the general survey may be due to the amalgamation of data from years 1, 2 and 3 of set-aside. Also, bare ground declined and perennial cover increased between years particularly in the field boundary, at the primary site, this may reflect the discontinuation of disturbance caused by farm machinery or agro-chemical usage.

Species richness of perennials, biennials and annual grasses did not vary greatly, but, annual dicots declined dramatically between years and never exhibited above ground, the species richness observed in the seed bank (Table 2). Chancellor (1985) found that many grassland weed seeds had a short life span in the soil and therefore the trend towards grassland species is interesting given that the primary site had been sown predominantly to cereals for at least the last decade. This suggests that all three sources of origin mentioned earlier were influencing the vegetation. Ingress from the boundary and insitu spread was shown by species that can spread vegetatively such as A. stolonifera, E. repens and Glechoma hederifolia. Other species, observed mainly in the field area, established from wind dispersed seeds and included Sonchus spp., Crepis spp., Senecio jacobaea and Taraxacum officinale. Species originating from the seed bank were mainly annuals and included Viola arvensis, Veronica arvensis and those with shorter lived seeds banks such as B. sterilis and B. mollis. Thus the data suggest that during succession of previously arable land there is a shift away from species that rely on the seed bank towards those with other means of regeneration.

ACKNOWLEDGEMENTS

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SHORT-TERM EFFECTS OF SET-ASIDE MANAGEMENT ON THE SOIL SEEDBANK OF AN ARABLE FIELD IN SOUTH-EAST SCOTLAND

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ABSTRACT

Increases in the seedbanks of several annual arable weed species, especially Poa annua, during the establishment of set-aside were reduced by a sown grass cover. Although Capsella bursa-pastoris seeded profusely on all plots in the first year, its seedbank fell by 73% over a two year period, whereas that of Senecio vulgaris expanded 23-fold. Seedbanks of neither of these two species were influenced by the presence or absence of sown grasses. However, C. bursa-pastoris was the only species to show a response to cutting regime; more seeds were recovered after two years from plots cut 3 times a year than from those cut only once. Biennial and perennial species, especially Cirsium vulgare, gradually colonised the plots after establishment, with plant counts also showing considerable suppression on grassed plots and no response to frequency of cutting. Seed numbers of these species showed similar trends, but were not yet sufficiently high after two years to show significant treatment differences.

INTRODUCTION

A major concern about the types of set-aside management which can be practised under existing legislation is the long-term effect on the seedbank of weeds in the soil and the consequences which this might have once the field returns to normal arable rotation. Another concern is the possible build-up in set-aside fields of populations of species which could become a nuisance to adjacent fields still under arable cultivation. Results after two years of set-aside management of a previously intensive arable field give an indication of how various management factors are changing the seedbank and weed populations and how major increases in problem species might be avoided.

MATERIALS AND METHODS

Full details of the site, its history and current management have been reported elsewhere (Fisher et al., 1990). Briefly, the experiment was laid out in April 1989 on cereal stubble with two replicates of 11 treatments. Plot size was 45 m by 15 or 10 m. Within the 11 treatments was a 3 x 3 factorial combination. This paper concentrates on the factorial part of the experiment, with the following treatments:

Sward type	Cutting regime
Fallow (natural regeneration)	Cut once (August), cuttings left
Perennial ryegrass (cv. Wendy)	Cut 3 times (June, August, October), cuttings left
Red fescue (cv. Logro)	Cut once (August), cuttings removed

In April 1989, plots due to be sown with grasses were given shallow cultivation and the seeds were harrowed into a moist seedbed. No soil cultivation occurred on fallow plots. Fixed quadrats were established at five locations in each plot (approximately 9 m apart up the centre line of the plot). Weed counts were made periodically at these points and percentage ground-cover scores for individual species taken at regular intervals. Soil samples (5 cm diameter cores to 20 cm depth) were taken immediately adjacent to the fixed quadrats in April 1989 and April 1991. The soil samples were stored at -20°C until required. After thawing and thorough mixing, a 200 ml sub-sample was extracted for analysis by sieving and flotation (as described in Wilson & Lawson, 1992). Seed and weed counts from individual quadrat points were pooled for statistical analysis, which was carried out after square root transformation of the data.

RESULTS

Establishment of the sown grass swards during 1989 was slow. By July, C. bursa-pastoris was seeding profusely over the whole area, especially on plots cultivated before sowing. P. annua dominated the fallow plots, with S. vulgaris and C. vulgare also important. Matricaria spp. and Stellaria media were well represented on the sown plots. Annual arable weeds provided almost 40% of the ground-cover on the fallow and fescue plots in July, rather less on the ryegrass plots. During 1990 and 1991, ground-cover by the sown grasses developed steadily and annual weeds contributed relatively little to the sward on these plots. This was not the case on fallow plots, where P. annua occupied over 25% of the plot areas in both 1990 and 1991. Sonchus asper and Galium aparine appeared for the first time on fallow plots in 1990. Biennial and perennial species have progressively colonised the fallow plots and to a much lesser extent the sown grass plots since 1989. Those contributing substantially to the sward have included C. vulgare (20% ground-cover on fallow plots in 1991), Taraxacum officinalis, Rumex spp., Urtica dioica and Ranunculus repens. Periodic scores over the first three years have shown no evidence that ground cover by sown grass or weed populations was affected by the cutting regimes imposed. Fuller details on sward development are available in the paper by Fisher & Davies (1991).

Overall changes in the soil seedbank during the first two years are summarised in Table 1. In April 1989 the seedbank was dominated by C. bursa-pastoris, with Matricaria spp., P. annua, S. vulgaris, S. media and U. dioica well represented. Numbers of seeds of C. bursa-pastoris and Matricaria spp. declined sharply thereafter, whereas those of P. annua and S. vulgaris increased very considerably. Most other species in the Table, with the exception of U. dioica, registered a small increase. Occasional constituents of the seedbank at either date included Rumex spp., Juncus effusus, Spergula arvensis, R. repens, Polygonum persicaria, Veronica arvensis, G. aparine,

TABLE 1. Principal species recovered from the soil seedbank before and two years after the establishment of set-aside plots.

Species	No. of seeds/m² (to 20 cm depth) - general mean of all plots 1989	1991
Capsella bursa-pastoris (L.) Medic.	28300	7590
Matricaria spp.	2800	0
Poa annua L.	770	19500
Senecio vulgaris L.	590	13300
Stellaria media (L.) Vill.	233	760
Urtica dioica L.	211	78
Polygonum aviculare L.	44	330
Myosotis arvensis (L.) Hill	11	440
Fallopia convolvulus (L.) A. Loeve	11	200
Cirsium vulgare (Savi) Ten.	11	56
Sonchus asper (L.) Hill	0	1910
Rumex spp.	0	100
Total	33500	45200

TABLE 2. Response of seedbanks of major species to two years of set-aside management.

Sward type	Cutting† regime	Mean no. seeds/200 ml soil sample in April 1991‡ C.b-p	P.a.	S.v.	M.a.	S.a.
Fallow	1 (L)	2.06	8.18	0.94	1.08	2.26
	3 (L)	2.59	5.01	2.65	0.81	1.73
	1 (R)	1.29	5.05	0.51	0.95	1.48
Ryegrass	1 (L)	1.15	0.82	1.18	0.60	0.67
	3 (L)	4.59	1.31	0.85	0.88	1.11
	1 (R)	1.72	1.88	1.11	0.66	0.76
Fescue	1 (L)	1.74	1.28	1.99	0.60	0.72
	3 (L)	3.15	2.26	5.77	0.66	0.61
	1 (R)	1.17	0.34	1.22	0.60	0.71
S.E. mean ±		1.004	1.597	1.895	0.188	0.431
Sig. of effect						
Sward type		NS	*	NS	NS	*
Cutting regime		*	NS	NS	NS	NS
Interaction		NS	NS	NS	NS	NS

Key: C.b-p - Capsella bursa-pastoris P.a. - Poa annua S.v. - Senecio vulgaris
M.a. - Myosotis arvensis S.a. - Sonchus asper

* = Effect significant at the 5% level

† = 1 = Cut once in August with cuttings left (L) or removed (R)
3 = Cut three times - June, August, October, with cuttings left (L)

‡ = Transformed data ($\sqrt{x + 0.375}$) using 1989 values as co-variates, except for Sonchus asper, which was not recorded in 1989.

Chenopodium album, raspberry and tree seeds and volunteer barley. Despite the large decline in numbers of the two main contributors to the seedbank in 1989, the total numbers of seeds recovered increased by approximately one-third over the two years.

With the more abundant species in the seedbank it was possible to investigate reactions to the factorial treatments applied using covariance on original populations as co-variates, where appropriate (Table 2). More seeds of S. asper, Myosotis arvensis and particularly P. annua were recovered from fallow plots in 1991 than from sown grass plots. Despite the decline in overall seed numbers of C. bursa-pastoris across the site, there were more seeds in 1991 on plots which had been mown three times a year than on those cut only once. However, the seedbank of this species on fallow plots was no greater than on sown plots. No other species showed any response to cutting regime. Although there had been a massive increase in seed numbers of S. vulgaris across the site, this did not appear to relate to experimental treatments.

For direct comparison with seedbank records, counts of the principal broad-leaved weeds recorded from the fixed quadrats in December 1991 are presented in Table 3. These show that the main concentrations of weed plants were on the fallow plots, with no obvious differences between ryegrass and fescue plots. There was no evidence that frequency of cutting, or the removal of the cut vegetation influenced the abundance of individual species. Other, less frequently recorded constituents of the above-ground flora, particularly on fallow plots, included Rumex spp., Plantago spp., J. effusus, Tussilago farfara, Senecio jacobaea, R. repens, U. dioica, and Cirsium arvense. Of the grass species P. annua was still a major component of the sward on fallow plots, while occasional patches of Elymus repens and Bromus sterilis were also recorded on these plots.

DISCUSSION

Two types of response by the weed flora were noted in above-ground records as the experiment progressed. Firstly, initially high plant populations of mainly annual arable species during the establishment phase were considerably reduced (other than with P. annua and S. vulgaris) in later years. Secondly, there was gradual colonisation and spread thereafter by biennial and perennial species. Changes in the seedbank of annual species largely agreed with above-ground records, with major overall increases in P. annua (up 25-fold), S. vulgaris (up 23-fold), and S. asper (not recorded in 1989). For most annual species any increases in the seedbank would have happened in the first year, since they produced few if any seedlings thereafter. The exceptions were P. annua, S. vulgaris and S. asper which were able to exploit bare patches on fallow plots in later years. The substantial decline overall in seed numbers of C. bursa-pastoris despite major seed shedding in the first year may indicate that much of the new seed did not enter the seedbank, possibly due to predation. Almost all the biennial and perennial species recorded as plants were also found in the seedbank, but numbers of seeds recovered were not sufficient after only two years to demonstrate treatment effects, even for C. vulgare. Subsequent increases are more likely to occur on fallow plots, although this could be blurred by wind and bird dispersal to adjacent plots. The general increase in the seedbank of S. vulgaris could perhaps be explained by wind dispersal rather than by in situ plant numbers on individual plots.

The main treatment factor influencing seedbank and weed populations was the presence or absence of a grass cover crop. Despite the additional germination of annual weeds stimulated by soil disturbance at sowing time, seedbank and weed populations after two years were usually greater or no less on fallow plots than on sown plots. It did not appear to matter whether the sown species was ryegrass or fescue and it is likely that the contrast between sown and unsown plots would have been even greater had the grasses established more quickly. On adjacent plots where white clover was sown with the ryegrass and greatly improved early ground-cover, many fewer weed plants have been recorded. (Fisher & Davies, 1991). These authors also suggested that the problem of stimulating germination of annual weeds during the sowing of a cover crop at the commencement of set-aside could be avoided by undersowing in the previous cereal crop, where the weed seedlings could be controlled by herbicides and competition from the crop. This could also help to avoid major seed return during establishment by species such as C. bursa-pastoris and S. vulgaris, whose seedbanks were not reduced by the cover crops in this experiment.

TABLE 3. Major broad-leaved species present on set-aside plots in December 1991

Sward type	Cutting† regime	C.v.	T.o.	E.s.	S.v.	C.f.	G.a.
		Mean no. weeds/m^2 ($\sqrt{x}$ + 0.375)					
Fallow	1 (L)	6.48	3.86	3.84	3.24	1.78	1.92
	3 (L)	4.10	4.60	2.92	2.91	2.45	1.37
	1 (R)	5.27	3.29	2.11	2.69	1.60	1.82
Ryegrass	1 (L)	1.13	0.80	0.61	0.61	0.61	0.61
	3 (L)	1.46	0.61	0.61	0.61	0.61	0.71
	1 (R)	1.95	0.98	0.61	0.61	1.02	0.61
Fescue	1 (L)	1.14	1.08	0.61	0.61	0.61	0.61
	3 (L)	1.27	1.14	0.61	0.61	0.61	0.61
	1 (R)	2.79	1.16	0.71	0.61	0.61	0.61
S.E. mean ±		0.655	0.405	0.724	0.327	0.446	0.485
Sig. of effect							
Sward type		***	***	**	***	*	*
Cutting regime		NS	NS	NS	NS	NS	NS
Interaction		NS	NS	NS	NS	NS	NS

Key: C.v. - Cirsium vulgare T.o. - Taraxacum officinale
E.s. - Epilobium spp. S.v. - Senecio vulgaris
C.f. - Cerastium fontanum G.a. - Galium aparine spp.
*,**,*** = Effect significant at the 5%, 1% or 0.1% level
† 1 = Cut once in August with cuttings left (L) or removed (R)
3 = Cut three times -June, August, October, with cuttings left (L).

The seedbank of most annual species was unaffected by the cutting regimes imposed, the exception being C. bursa-pastoris. The recovery of more seeds of this species from regularly cut plots than from those cut only once a year may reflect decreased competition from taller species topped by the mower in the first year, or a more favourable environment for seedling establishment and survival on these plots in the second year. Seedbanks of biennial and perennial species were too low in April 1991 to show responses to this factor, but neither were they shown by plant numbers recorded in the following December. Although the three-cut regime looked much tidier, it had little effect on the botanical composition of the swards, compared with a single cut in August. Leaving or removing the large amount of vegetation cut at this date on grass plots also had no effect on sward composition. It remains to be seen whether or not further treatment differences in response to cutting management appear in the seedbank over the longer term. To date, the presence or absence of a cover crop has influenced sward and seedbank composition more than the frequency with which the sward has been cut and whether or not the cuttings have been removed.

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SIGNIFICANCE OF THE SEED RAIN FROM SET-ASIDE

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ABSTRACT

Seed rain was monitored, using gravel traps, on set-aside and adjacent crop areas between June and November 1991. The data showed that set-aside can produce very high numbers of seeds. Species composition and numbers of seeds were variable over set-aside areas, but in each trap only a few species made up a large percentage of the seeds caught. Seed rain on cropped areas was minimal in comparison with set-aside. Dispersal into cropped areas from set-aside, although small in terms of total seed production on set-aside was large in comparison to seed production within the crop. Dispersal from set-aside source areas was largely restricted to the crop edges. Temporal variation, between species, of seed shedding was detected.

INTRODUCTION

An integrated project on plant and animal dynamics on set-aside land has been carried out at Aberdeen University's Aldroughty farm near Elgin in north east Scotland. The three main components of the plant study have involved assessment of the vegetation, seed bank and seed rain. The influence of the set-aside vegetation on the adjacent crop and the extent of invasion of set-aside from adjacent semi-natural areas was one focus of the study.

The input of propagules into a habitat represents the potential population of the area (Harper, 1977). In primary succession, the seed bank and seed rain influence the botanical composition of the vegetation (Marshall & Hopkins, 1990). On set-aside the initial floristic composition will be determined by the seed bank. Thereafter the seed rain will become more important. Because of the short time scale of the set-aside scheme, the effects of the seed rain are likely to be important, both by dispersing into neighbouring crops and in subsequent crops on set-aside land returned to arable use. This paper will present measurements of the seed rain which were made during the summer of 1991, and discuss the implications of these results.

METHODS

Study Site

Set-aside strips were established in two fields adjacent to semi-natural areas. In Field A, a set-aside field edge approximately 40 m wide and 110 m long, was established in October 1988, thus forming a corridor between a deciduous wood and a partially drained bog. In Field B, a series of eight plots 15 x 40 m, were set up in October 1989, forming a strip adjacent to the bank of the River Lossie. Using a randomised block design, four plots were set-aside and four continued under intensive arable management. In both fields set-aside vegetation was allowed to regenerate naturally from stubble and was cut only once a year in late September. For a more detailed description of the sites see Jones *et al.*, (1991). In 1991 the crop in Field A was potatoes and in Field B was spring barley. Herbicides were included as part of the management regime applied to these crops.

Seed trap design

Traps were based on a design by Johnson and West, (1988). A 20 cm length of 10.5 cm diameter plastic drain pipe was sunk into the soil, a 10 cm diameter funnel was slotted into this, plugged with cotton wool to allow drainage of rainwater and filled with 6 mm gravel to lie flush with the soil surface.

The gravel was changed every two weeks to avoid germination of seeds and to reduce the effects of predation. Seeds were extracted from the gravel by washing them out using a vibrating sieve and floated off with a saturated solution of calcium chloride. Seeds were picked out individually, and viable ones were identified and counted.

Trapping regime

In Field A two parallel transects were established 40 m apart, running through the set-aside and the adjacent crop. Five seed traps were placed within each of eleven 1 m^2 quadrats, 10 m apart, along each transect. In each plot in Field B, 12 traps were placed in 2 rows of 6 (5 m apart) giving a total of 48 traps on set-aside and 48 in the crop. Trapping began at the end of June and continued until mid November.

RESULTS

Nearly 120 000 individual viable seeds were recovered, identified and counted (Table 1). Only 2% of these were recovered from cropped areas despite there being the same trapping effort as on set-aside areas. The numbers represent nearly 200 000 seeds/m^2 on the set-aside in Field B.

Table 1. Total numbers of seeds caught during 1991.

	Crop		Set-aside	
	Total	m^{-2}	Total	m^{-2}
Field A (55 traps)	294	681	41 319	95 653
Field B (48 traps)	2 069	5 488	74 800	198 413

The seeds shed in Field A showed variation both in species composition and in numbers of individuals at different positions in the field (Fig. 1). In each quadrat the seed rain was dominated by only a few species. Some species, notably *Holcus lanatus*, made an important contribution to the seed rain in almost every quadrat along the transect. Others, for example *Dactylis glomerata*, only formed a significant part of the seed rain on a local scale. Similarly, in Field B, only a few species were important in each set-aside plot, despite the fact that seed rain samples were taken from a much wider area than in Field A. An extreme example of a small number of species dominating the seed rain is shown in plots 6 and 7 where *Holcus lanatus* and *Senecio jacobaea* together accounted for over 95% in each plot (Fig. 2).

Peak deposition of seeds for each of these species occured at different times (Fig. 3). *Spergula arvensis* had a peak early in the season, whereas the seeds of *Senecio jacobaea* were shed much later. A seed rain peak was observed for most species in the fortnight around 25th

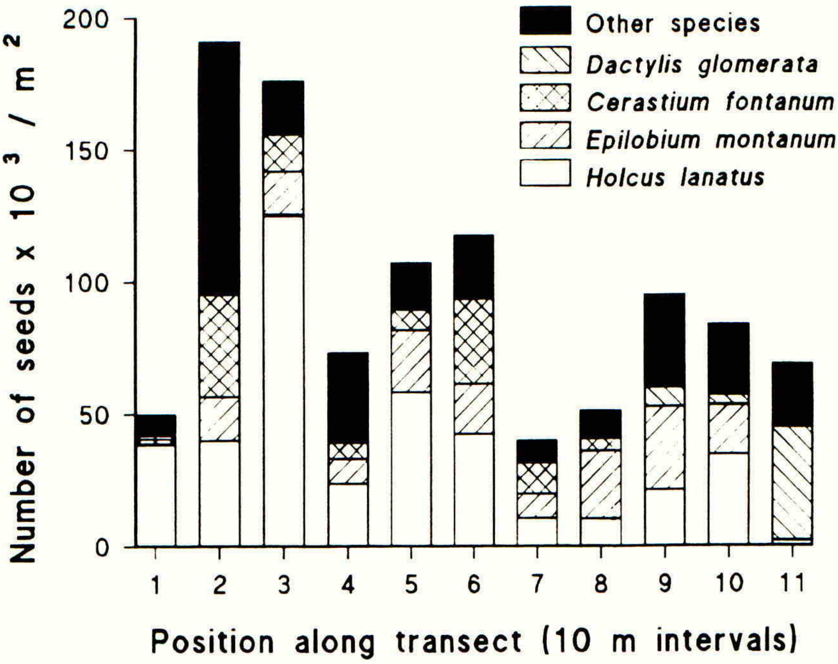

Figure 1. Total number of seeds of selected species caught in Field A.

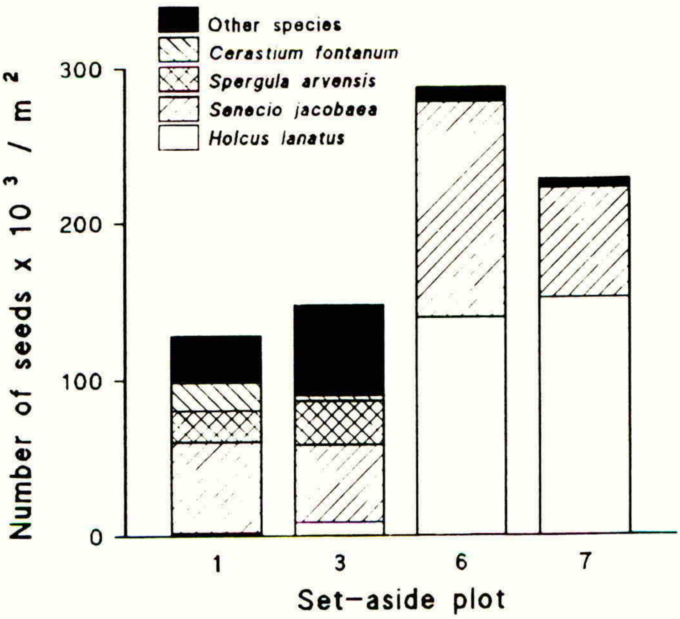

Figure 2. Total number of seeds of selected species caught in set-aside plots in Field B.

September, coinciding with the time of vegetation cutting, which took place in the middle of this two week period.

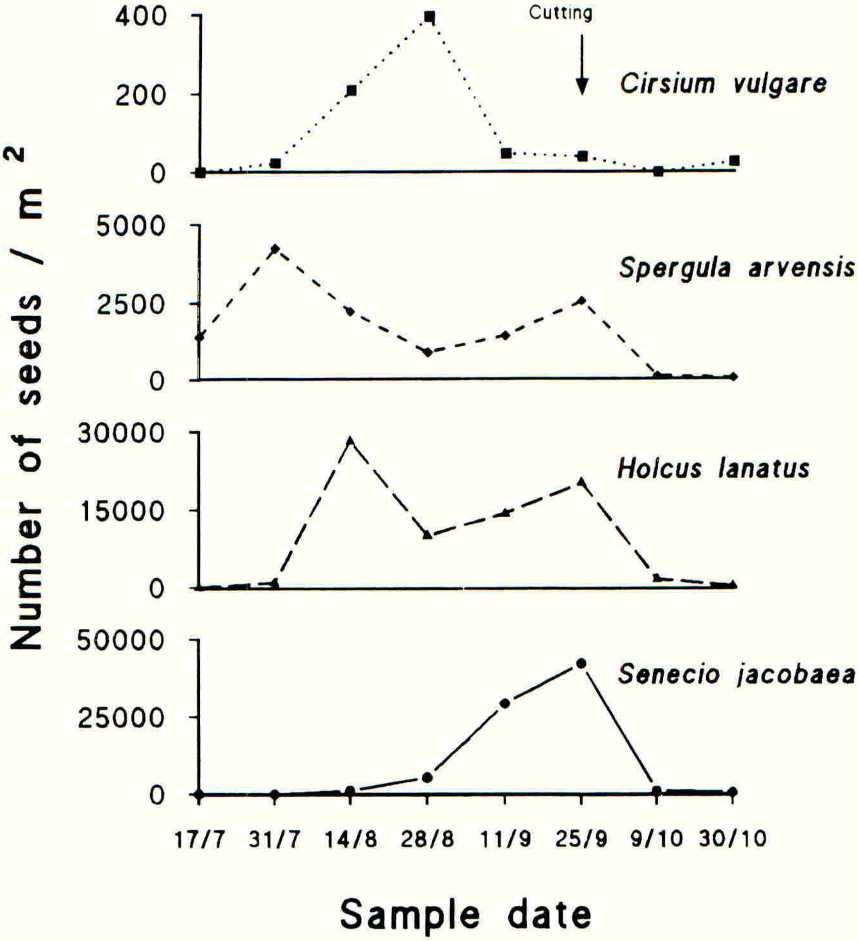

Figure 3. Temporal variation of four selected species in Field B. Each data point represents the seed rain onto set-aside (total in 48 traps) over a two week period and is plotted at the mid point of the period.

Seeds caught in the crop, but of species which were not present in the crop as plants, were assumed to have dispersed from the set-aside. The most important of such species were *Senecio jacobaea* and *Holcus lanatus* which accounted for 70% of the dispersal from set-aside into the crop. Only 0.4% of the total number of seeds produced on the set-aside in Field A, and 0.9% of those produced on the set-aside in Field B dispersed into the adjacent crop areas, although they represented 63% and 32% respectively of the seeds captured there.

Of those seeds which did disperse into the crop (approximately half of which were *Senecio jacobaea*) a large proportion were caught close to the set-aside source (Figure 4). Although some seeds from species in set-aside may have dispersed up to 72.5 m into the crop, 46.9% of them were caught within 12.5 m of their source area.

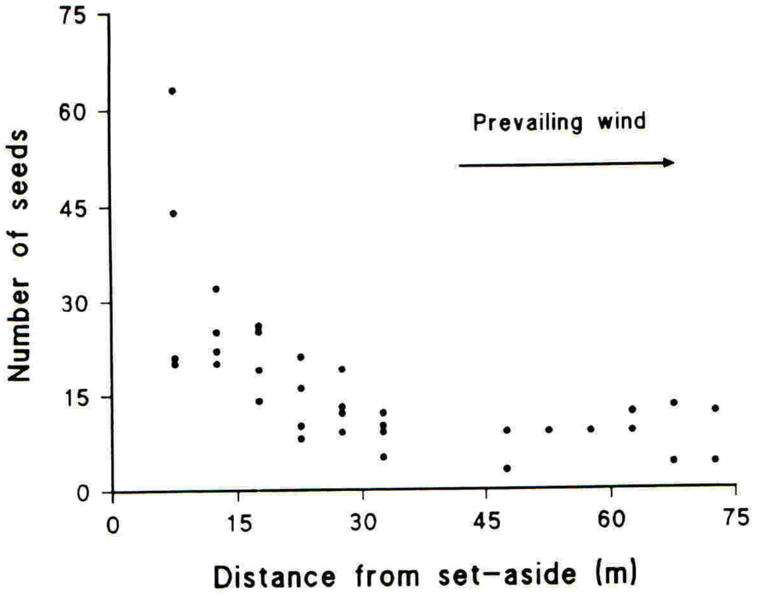

Figure 4. Number of seeds which dispersed from the set-aside into the crop at distances from the set-aside down the direction of the prevailing wind in Field B.

DISCUSSION

These results clearly show that set-aside areas left to regenerate naturally have the potential to produce enormous numbers of seeds, far in excess of the number produced on adjacent cropped areas where herbicide use has permitted only very low plant populations. This seed rain constitutes an important potential food source for a variety of spermophagous animals, from insects to small mammals and birds and may lead to a greater abundance and diversity of such fauna. This level of seed production, however, implies the development of a large seed bank under set-aside, since species such as *Holcus lanatus* and *Spergula arvensis* are known to form persistent seed banks (Grime, 1979; Roberts & Feast, 1972). Soil cultivation, to return set-aside areas to arable use, may thus produce severe weed infestations of both annual arable species and of other aggressive species which would not normally be expected in such high numbers on arable land. After two or three years under set-aside the seed rain on these plots has become dominated by a small number of largely annual arable and competitive ruderal species. These are species which exploit disturbed areas (Grime, 1979).

Dispersal of seed from set-aside into the crop presents a further potential problem for agriculture. The numbers which dispersed into cropped areas imply that land adjacent to set-aside might suffer very low levels of contamination in comparison to the set-aside. However, because these numbers represent a proportionally high input in comparison with that from the cropped area itself, this inward dispersal from set-aside may constitute an increase in the occurrence of weeds in the crop. This might be a problem for nature conservation if it encouraged an increase in the level of herbicide spraying or discouraged low input farming. However recent reductions in farm support through the CAP will raise the economic threshold for chemical weed control. Also, the short dispersal distances demonstrated here (which agree with the observations of Poole & Cairns, 1940) suggest that only crop margins may suffer severe weed infestation from set-aside.

The temporal variation in seed shedding has implications for management of set-aside land. Timing and/or frequency of cutting might have prevented the enormous number of *Senecio jacobaea* found in the seed rain in Field B. Decisions on cutting time and frequency can be used as management tools to manipulate the vegetation on set-aside. An increase in the frequency of cutting may reduce seed numbers in the seed rain, however, it may be that species might respond by modifications to their growth habit and set seed below the level of cutting.

ACKNOWLEDGEMENTS

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EFFECT OF ROTATIONAL FALLOW ON WEED INFESTATION

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ABSTRACT

A two year field trial was carried out to investigate the effect of natural regeneration and various autumn- and spring-sown cover crops on weed infestation in the fallow and the following winter wheat. All plots were cut to prevent seeding of weeds and cover crops. In the fallow, weed suppression differed according to the cover crop used. After cutting only the white clover-perennial ryegrass mixture regenerated sufficently to give a complete ground cover. The effect of the cover crop on weed infestation was also evident in the following winter wheat. With ploughing after the fallow and efficient weed control, weed problems and yield losses are not expected.

INTRODUCTION

Since 1988 farmers have been able to take part in the set-aside program of the EC. The aim of the voluntary program is to reduce surpluses of arable crops. For the land taken out of production, annual compensation payments are given. In West-Germany about 65 % of land set aside is in permanent fallow and 35 % in rotational fallow. Fallowed land has to be managed within defined conditions. It must be covered either with sown plants (harvestable crops are allowed in Germany) or with natural regeneration, no fertilizers and pesticides may be used, and the land must be managed especially to control weeds.

In autumn 1989 a field trial was started to investigate the effect on weed infestation of various cover crops in rotational fallow. Weeds were studied during the fallow period and in the following winter wheat. Different autumn- and spring-sown species were used as cover crops. The effect of the cover crops on weeds was compared with natural regeneration.

MATERIALS AND METHODS

The field trial included two phases, which were carried out successively on different arable fields. After harvest of the preceding winter wheat, soil was cultivated with a rotary cultivator and the winter cover crops: winter rape (*Brassica napus*), winter rye (*Secale cereale*), subterranean clover (*Trifolium subterranneum*) or white clover/perennial ryegrass *(Trifolium repens/Lolium perenne*) (only in 1991)) were sown in August. After a second shallow cultivation in March spring cover crops: white mustard (*Sinapis alba*), oats (*Avena fatua*) or field bean (*Vicia faba*) were sown. In addition to the cover crops, plots with natural regeneration were included. The field trials were planned as a randomized block-design with 3 replications. The plot size was 14 m x 7.5 m. The autumn-sown cover crops and the plots with natural regeneration from autumn were cut in June, the spring covers in July. The plant material was left on the field.

Each set-aside year was followed by 2 years of winter wheat. The fallowed land was ploughed before sowing the following winter wheat in October, and again before sowing the second wheat crop. In winter wheat, fertilizer and herbicides were used at conventional levels. Fungicides were not used in order to investigate the occurrence of diseases (not reported in this paper). In the fallow, ground cover from cover crops and weeds was estimated several times. In the following winter wheat, weeds were counted and crop yield determined. Both were subjected to analysis of variance and separated by Tukey's test.

RESULTS

Number of species and weed density

In the 2 fallow years, 51 weed species were found. The main weed species in autumn- and in spring-sown covers were *Chamomilla recutita*, *Lamium purpureum*, *Stellaria media*, *Thlaspi arvense*, *Veronica persica*, *Alopecurus myosuroides*, *Poa annua* and volunteer wheat. These species represented about 90 % of the total weed infestation. The number of species in the different treatments varied between 22 and 32 in the first and 14 and 23 in the second year. There were only little differences in species composition between autumn and spring covers. Weeds as *Elymus repens* or *Cirsium arvense* which are difficult to control in a following crop were not present in this field trial as well as rare or endangered species. Average weed density was 175 plants/m^2 in the autumn and 111 plants/m^2 in the spring treatments. The second cultivation in spring especially reduced volunteer wheat and *Poa annua* and hence resulted in a significant lower weed density.

Ground cover from cover crops and weeds

The autumn-sown cover crops provided little ground cover before winter, except for subterranean clover (Fig. 1). All autumn-sown cover crops reached highest ground cover at the end of May. Both winter rape and winter rye produced relatively low ground cover. Highest ground covers were obtained by subterranean clover and white clover/ryegrass. After cutting white clover/ryegrass regenerated quickly and gave excellent ground cover. Due to the late cutting date there was little regeneration of the other cover crops. The spring-sown crops had highest ground cover at the end of June (Fig. 2). Field bean development was affected by a heavy aphid infestation in 1991.

Weed ground cover was clearly reduced by the cover crops (Figs. 1 and 2). Until cutting, subterranean clover, white clover/ryegrass and field bean had highest ground cover but this did not correlate with the low weed cover. After cutting those weed species which were little affected continued to grow in all treatments except for white clover/perennial ryegrass which quickly regained a good ground cover and suppressed weeds.

Weed infestation and yield in the following winter wheat

Weed infestation in winter wheat in the first and second year after fallow was influenced by the fallow treatments, but the effects in the first year were not significant (Table 1). In the first year after fallow, weed infestation, compared with the natural regeneration, was reduced between 35 - 70 % in the spring-sown and 3 - 46 % in the autumn-sown cover crops, except of winter rye, where weed infestation increased. Weed infestation of the second

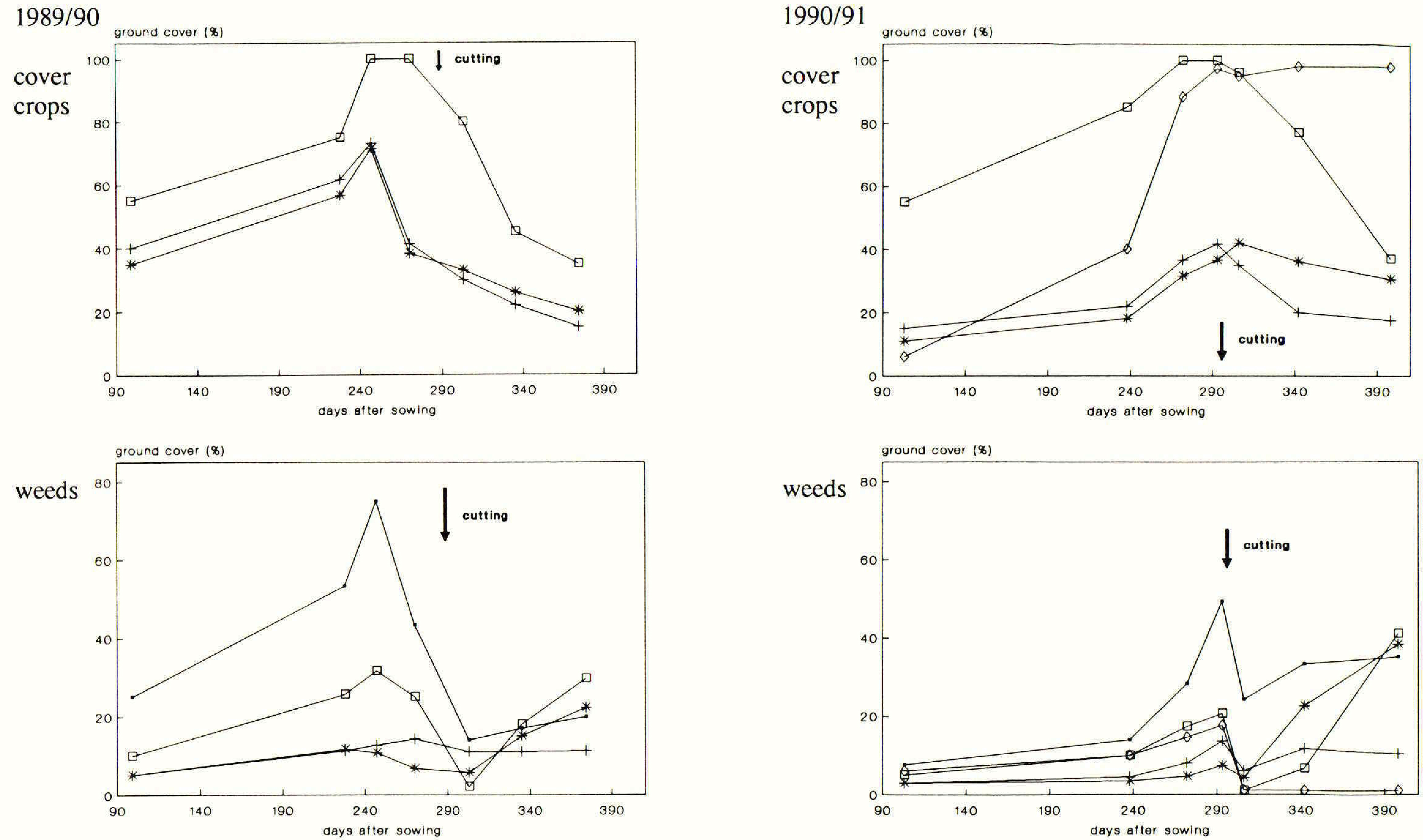

FIGURE 1. Development of ground cover (%) of autumn-sown cover crops and weeds

natural regeneration — winter rape — winter rye
subterranean clover — white clover/perennial ryegrass

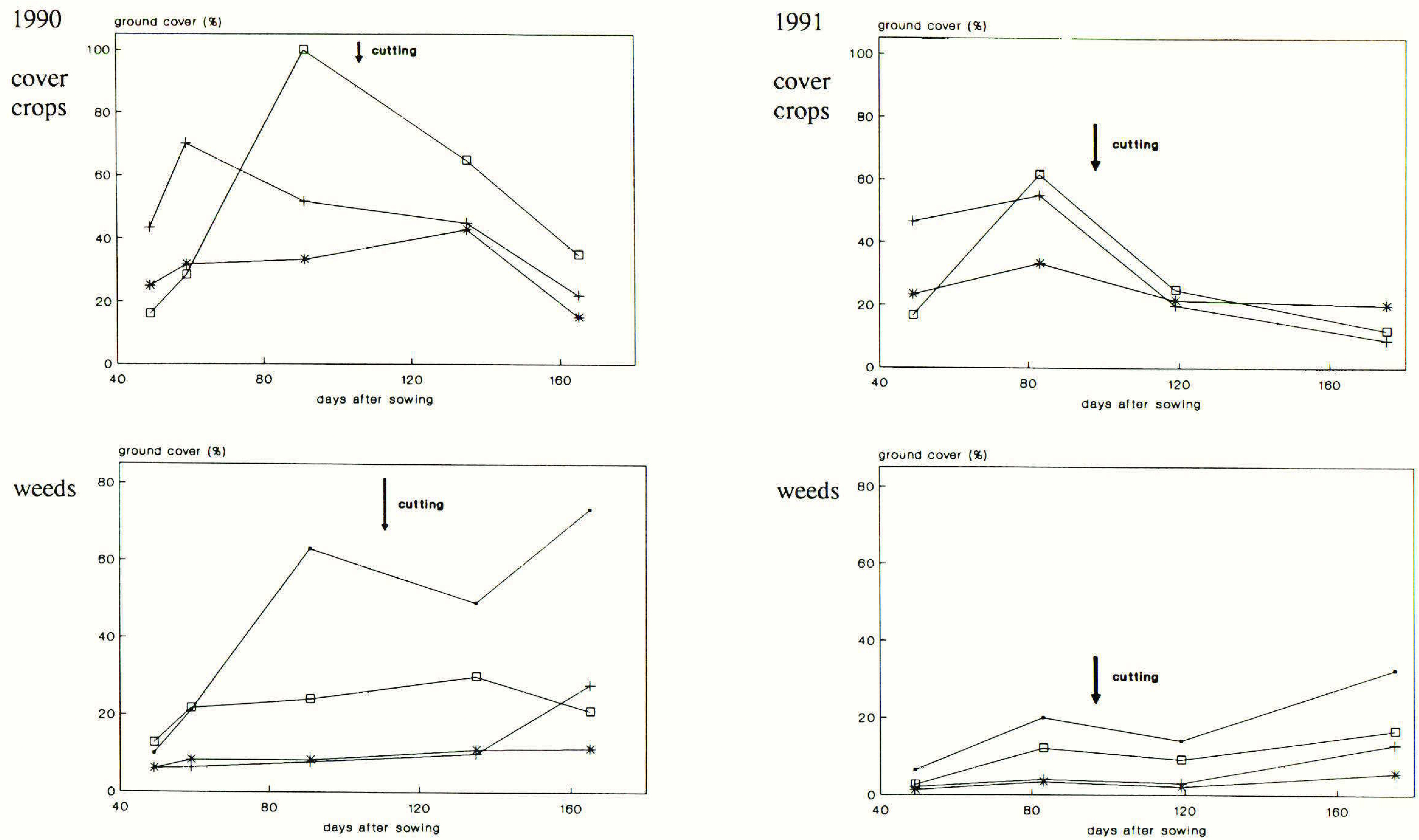

FIGURE 2. Development of ground cover (%) of spring-sown cover crops and weeds
natural regeneration — white mustard — oats — field bean

year was similar to the first year except for the natural regeneration in spring (Table 1). The high infestation was caused by *Chamomilla recutita*, whose seeding could not be prevented by cutting in the fallow period.

Winter wheat yield was not significantly affected by the different cover crops (Table 1).

TABLE 1. Effect of rotational fallow on weed infestation and yield in following winter wheat*

Year after fallow Treatment	phase	weed numbers first wheat plants/m²	 second wheat	yield first wheat t/ha
natural regeneration (autumn)	1	411	455	7.15
	2	261		
winter rape	1	331	393	7.65
	2	181		
winter rye	1	421	369	7.47
	2	440		
subterranean clover	1	222	262	7.71
	2	173		
white clover/perennial ryegrass	1	-	-	-
	2	254		
natural regeneration (spring)	1	479	1107	7.37
	2	429		
white mustard	1	247	249	7.40
	2	174		
oats	1	191	177	6.90
	2	127		
field bean	1	249	418	7.59
	2	277		
minimum significant difference	1	n.s.	200.4	n.s.
(Tukey; 0.05)	2	n.s.		

* weeds and yields of phase 2 were not assessed

DISCUSSION

Farmers, participating in the set-aside program, do not want an increase in weed infestation by fallowing. The experiment shows that cover crops suppress weeds in rotational fallowing. The effectiveness of the various cover crops was different and cannot simply be explained by their ground cover development. Weed ground cover in winter rye and in winter rape was lower than in subterranean clover despite lower ground cover by the rye and rape. Similarly field bean had more ground cover than oats or white mustard but allowed more weeds. It is obvious that in addition to the ground cover other effects do influence weed suppression, like allelopathy in winter rye (BARNES *et al.* 1987), or rapid plant growth (Zink and Hurle, 1989). On the other hand, under legume covers more nitrogen is available for the weeds, causing better weed growth and coverage.

After cutting, cover crops with no regeneration capacity loose their suppressive effect. Nevertheless, cutting is necessary to prevent seeding of weeds and cover crops (Clarke and Froud-Williams, 1989). In our experiments only white clover/perennial ryegrass regenerated after cutting and suppressed the weeds during the whole fallow period. Fisher and Davies (1991) and Maykuhs (1991) described clover/grass mixtures as a very competitive cover crop suitable for weed management in set-aside.

Even with spring sown cover crops, good weed suppression is possible, but uncovered soil during winter can cause soil erosion and loss of nutrients.

No set-aside treatment makes possible a complete prevention of weed seeding but, as Forche (1991) has already pointed out, weeds should not raise severe problems in the following crop and yield losses are not expected with ploughing after fallowing and efficient weed control. However, problems may arise if fallowed land is infested with perennial weeds which especially develop well under natural regeneration. In this case the use of non selective herbicides before planting the next crop could be advisable.

ACKNOWLEDGEMENT

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VEGETATION CHANGES AND WEED LEVELS IN SET-ASIDE AND SUBSEQUENT CROPS

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ABSTRACT

The results of two series of experiments, each at five sites are reported. One series examined the effects of rotational (one-year) set-aside over a three year period and the other the first two years of permanent (five year) set-aside. A range of plant covers were sown, including rye-grass, white clover and allowing natural regeneration of the previous cereal crop. Plots were either mown to prevent seeding or once per year in August/September. In the rotational experiment and the first two years of the permanent experiment cutting on 2-3 occasions was required to prevent seeding on lighter soils and on heavy soils 4-5 cuts were required. In early seasons seedheads were present in early April. Numbers of volunteer cereals in plots were similar for all treatments in the first year. However, the management in the first year had a significant effect on their survival and sowing a plant cover or cutting more than once reduced them to negligible levels. Where a plant cover has been sown this has dominated the vegetation and in some cases almost excluded other species by the end of the first year. Natural regeneration has resulted in the greatest diversity of species present. In the rotational experiment and the first year of the permanent experiment these were predominantly annual species. In the second year of the permanent experiment perennial species have become established. No weed problems have been encountered in the cereal crop following rotational set-aside.

INTRODUCTION

The EC set-aside scheme came into operation in the UK in July 1988. The 5 year scheme was voluntary and designed to reduce surpluses of arable crops. In return for taking at least 20% of eligible arable land out of production on a holding, annual compensation payments of up to £222/ha were available. Set-aside land could be rotated annually or remain in the same place for up to 5 years. Set-aside land had to be managed within defined conditions which included a requirement to establish a green plant cover, or, if the previous crop was cereals or grass, natural regeneration was permitted. The plant cover had to be maintained without the use of fertilisers or pesticides, although under certain conditions some herbicides could be used. Cultivations were allowed to control weeds (provided a plant cover was re-established) or to establish a plant cover. Land set-aside had to be cut at least twice during the set-aside year. One of these cuts had to be in the months of July or August and 2 cuts had to be at least one month apart.

In August 1991 another scheme, the EC one-year set-aside scheme, was introduced, for one year only, in the UK. Again this was voluntary. Under this scheme farmers were offered up to £121.20/ha plus a refund of co-responsibility levy money paid on all cereals produced between 1 July 1991 and 30 June 1992. In return farmers had to set-aside at least 15% of their arable area used to produce specified crops for the 1991 harvest. Within this requirement they also had to reduce their cereals area by 15%. The management conditions of this scheme were broadly similar to the 5 year scheme with the exception that a green plant cover must be sown (natural regeneration is allowed over the winter period if a green plant cover is sown in the spring).

After the 4 years of the schemes a total of about 167,000 ha (nearly 5% of the total cereal area) of land is now set-aside in the UK.

In May 1992 it was announced that set-aside would be part of the reform of the EC Common Agricultural Policy. Farmers will be required to set-aside 15% of their area of cereals, oilseeds and protein crops. The full details of requirements and management conditions have not yet been announced.

MATERIALS AND METHODS

This paper includes work on both rotational and permanent set-aside at five ADAS Research Centres. (Table 1). In all cases the previous crop was winter wheat.

TABLE 1. Sites and soil types where the experiments are located.

Site	Soil Type	Textural Classification
1. Boxworth, Cambs	Silty clay	Heavy
2. Bridgets, Hants	Silty clay loam	Medium (calcareous)
3. Drayton, Warwicks	Clay	Heavy
4. Gleadthorpe, Notts	Sandy loam/loamy sand	Light
5. High Mowthorpe, Yorks	Silty clay loam	Medium

Rotational (1 year) set-aside experiment

Three rotational set-aside treatment years were started annually (in Autumn 1987, 1988 and 1989) and each was followed by two test crops of winter wheat (or winter barley as the second test crop at Gleadthorpe) (Three phases). Plot size was about 24 m x 24 m and there were four replicates. In the first test year seven different nitrogen rates (0-280 kg/ha) were applied as sub-treatments. In addition to yield and optimum nitrogen rates the second test years were also monitored for take-all. In both years, plots were managed as appropriate for fungicides, growth regulators, insecticides and herbicides. New sites on the same farm were established for each phase. The full list of treatments are outlined in Table 2. Within this list of treatments the bare fallow treatment would not be eligible under the rules of set-aside.

During the treatment and test years plots were monitored for weed germination in the autumn, summer and spring by counting species in random quadrats. In phase I numbers/m^2 were recorded. In phases II and III weed frequency was recorded by subdividing each m^2 quadrat into 100 squares each of 10 cm x 10 cm. Frequency was recorded as the number of squares in which each species occurred. In the test years herbicides were applied to all plots post weed emergence and after early weed establishment had been monitored. There were also unsprayed areas in each plot.

TABLE 2. Treatments in rotational set-aside experiments

Established autumn 1987 (Phase I)

1. Chemical fallow with no cultivation. Weed growth controlled by repeat low doses of paraquat or glyphosate. Aim to prevent weeds seeding.
2. Bare fallow established by autumn ploughing and maintained by mechanical cultivation if possible. Herbicides only used if necessary to prevent weeds seeding.
3. Italian rye-grass "green cover". Established as soon as possible after harvest, topped during the growing season to prevent seeding.
4. Continuous cereal, normally winter wheat.
5. Natural regeneration of stubble, no cultivation or spraying. Plant growth controlled by repeat mowing to prevent seeding (not at all sites).
6. Forage rape sown in stubble. Destroyed and buried in spring. Fallow subsequently maintained by cultivation. Herbicides used if necessary (not at all sites).

Established autumn 1988 (Phase II) and Autumn 1989 (Phase III)

1. Bare fallow established as soon as possible after harvest using cultivations or glyphosate. Ploughed at least once.
2. Italian rye-grass established as soon as possible after harvest, repeated mowing to prevent seeding. Broken up after 1 August.
3. Continuous cereal, normally winter wheat.
4. Natural regeneration of stubble, no cultivation or spraying. Plant growth controlled by repeated mowing to prevent seeding.
5. Autumn fallow, spring legume established using a minimum of cultivation (not at all sites).

Permanent (5 year) set-aside experiment

A separate series of experiments was started in autumn 1989 (autumn 1990 at Gleadthorpe) which will last for seven years and examine the effects of permanent set-aside. This experiment is located on single sites at the same farms as the rotational experiment (Table 1). The treatments (Table 3) will remain for five years and be followed by two test years of winter wheat. In the first test year different rates of nitrogen will be applied with the intention of determining the optimum N rate required for yield. In the second test year take-all will also be monitored. Plots are 12 m x 24 m and there are 4 replicates at each site. Plant covers were sown in the autumn. Throughout the set-aside period, plots are being monitored for height, density and frequency of plant species present and effects on the soil seed bank in 6 fixed quadrats of $1m^2$ per plot.

Low nitrogen rye-grass would not be allowable under the rules of set-aside but has been included to generate data appropriate to the effects of a possible management regime in Nitrate Sensitive Areas (NSAs).

TABLE 3. Treatments in permanent set-aside experiment.

Plant Cover	Cutting Regime
1. Perennial rye-grass (PRG)	a) Once (August/September)
2. PRG/white clover (WC)	b) At least twice to prevent seeding, mowings left *in situ*
3. Natural regeneration (Nat Reg)	
4. Low nitrogen PRG	c) At least twice to prevent seeding, remove mowings
5. Normal arable rotation	

NB: Not all combinations of plant cover and cutting treatments are present.

RESULTS AND DISCUSSION

Cutting

It was the intention in the rotational experiment to prevent weeds from seeding by either mowing or cultivation. This reflects the importance of preventing weeds from taking advantage of the set-aside year to multiply in the absence of crop competition or herbicides (Wilson, 1988). Results from the rotational set-aside experiment confirm initial conclusions (Clarke & Froud-Williams, 1989) that on heavy, water retentive soils, cutting 4-5 times per year is required, whereas on medium and light soils, 2-3 times per year may suffice (Table 4). The exact number required will of course depend on rainfall pattern and increase with increased rainfall. In some seasons, such as 1988/89, seed heads were produced very early and the cutting programme needed to start in early April. A similar number of cuts have been required to prevent seeding in the permanent experiment in both the first two years. However, 1990 was a dry year and tended to require fewer cuts in both experiments. On the heavier soils at Boxworth and Drayton there was a tendency for natural regeneration to require one more cut per year than the sown covers to minimise seeding. In the third year of the permanent experiment differences in the cutting frequency required to prevent seeding are becoming apparent. For instance, at Boxworth in 1992 the natural regeneration plots have already required cutting on 4 occasions (up to early July) to prevent seeding of *Bromus spp*. By comparison the perennial rye-grass has required cutting on only two occasions. As there were no annual grass weeds in the perennial rye-grass plots the rye-grass, which is a late maturing variety, has dictated the need to cut.

Frequent cutting has been shown to alter the habit of *Alopecurus myosuroides*, *Bromus spp*. and volunteer cereals in these experiments so that seed heads were progressively lower after each cut. It is also interesting to note that the rolling effect of the tractor wheels could allow strips to remain uncut and therefore seed early, which emphasises the benefit of offset, rather than trailed or rear mounted mowers. The best cutting has resulted from flail rather than rotary action mowers. The flail mower has tended to give a better cut and chop the mown material more thoroughly leaving less dead material which can kill out the plant cover beneath.

TABLE 4. Frequency of mowing required to prevent cover seeding.

	ROTATIONAL EXPERIMENT : ITALIAN RYE-GRASS					
	1987/88		1988/89		1989/90	
Site	Date of 1st cut	No of cuts	Date of 1st cut	No of cuts	Date of 1st cut	No of cuts
Boxworth	1 June	3	31 March	4	12 April	5
Bridgets	26 May	2	25 April	3	10 April	2
Drayton	13 May	5	1 April	4	31 May	2
Gleadthorpe	14 June	2	11 May	3	11 June	2
High Mowthorpe	1 July	2	7 June	3	13 June	2

	ROTATIONAL EXPERIMENT : NATURAL REGENERATION					
	1987/88		1988/89		1989/90	
Site	Date of 1st cut	No of cuts	Date of 1st cut	No of cuts	Date of 1st cut	No of cuts
Boxworth	23 May	4	19 April	4	12 April	4
Bridgets	n.a.	n.a.	25 April	3	10 April	2
Drayton	n.a.	n.a.	14 April	5	31 May	2
Gleadthorpe	14 June	2	11 May	3	30 April	3
High Mowthorpe	n.a.	n.a.	7 June	2	13 June	2

	PERMANENT EXPERIMENT : NO OF CUTS					
	PRG		PRG/WC		Nat Reg	
Site	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Boxworth	2	2	2	2	2	3
Bridgets	3	3	3	3	3	3
Drayton	2	2	2	2	3	3
Gleadthorpe	3		3		3	
High Mowthorpe	1	2	1	2	1	2

n.a. = treatment not present

Vegetation patterns during set-aside period

In the permanent experiment the sown species became predominant by the end of the first year (Table 7). The clover has taken longer to establish but by the end of the second year was often more abundant than the rye-grass. Good covers of both these species suppressed the presence of other species. These findings are similar to those of Poulton & Swash (1992), Fisher & Davies (1991) and Forche (1991). In the rotational experiment the lowest number of species was found in the continuous cereal treatment where it appears the crop gave good suppression. In both experiments greatest diversity (Tables 5 and 7) was found on the natural regeneration plots where species found were mainly arable weeds such as *Bromus spp.*, *Cirsium arvense*, *Cirsium vulgare*, *Elymus repens*, *Poa spp.*, *Senecio vulgaris*, *Sonchus spp.* and *Stellaria media*. The species diversity on the natural regeneration treatments in the rotational experiment is illustrated by Table 6, although the assessments were made on adjacent experiment sites, but in the same year. Competitive and carpet dicots (dicotyledonous) and carpet grasses were all well represented in the set-aside treatment year and the following test crop year. In both experiments the species present were typical of the soil type and would be expected from past cropping history of the sites. The greatest number of species, up to 24, has occurred at the Bridgets site . Perennial species, especially, have increased in the second year. Seeds of many of these species are dispersed by wind and suppression is therefore important. Seed production has been eliminated by frequent cutting or the presence of a sown plant cover.

In the first spring, levels of volunteer cereals were similar between all treatments, irrespective of plant cover, at 3 of the 4 sites. Only at High Mowthorpe were they significantly higher on the natural regeneration plots. By autumn of the first year they were severely reduced on all treatments, tending to be highest on the single (August/September) cut natural regeneration. On only this treatment have volunteer cereals survived to the end of the second year in any number.

TABLE 5. Vegetation records in March/April in rotational experiment.

	Bare Fallow	Italian Rye-grass	Nat Regen	Cont Cereal	Aut Fallow Spr Legume
Five site mean of three phases (number of species/m^2)					
No. during set-aside	7.67	6.93	8.63	4.55	7.90[#]
No. in unsprayed areas in following wheat crop	7.30	7.40	7.70	6.73	6.95
Five site mean of last 2 phases (recording frequency/m^2)					
No. during set-aside	16.75	32.10	96.00	44.68	55.58
No. in unsprayed areas in following wheat crop	69.47	63.22	54.51	68.59	89.46[+]

[#]Mean of phases II and III only
[+]Reduced number of sites in the mean

TABLE 6. Number of sites with each classification of species on natural regeneration plots in rotational experiment in July/August 1990.

Classification Group	Set-aside year Phase III	Following wheat crop Phase II
Carpet dicots (eg Veronica, Aphanes arvensis)	5	3
Tall competitive dicots (eg Matricaria, Papaver)	5	4
Perennial dicots (eg C. arvense, Rumex)	4	1
Carpet grasses (eg Poa annua, Agrostis stolonifera)	4	4
Competitive grasses (eg A. myosuroides, Avena fatua)	2	4
Perennial grasses with storage organ (eg Arrhenatherum elatius)	1	3
Volunteer crop dicots and monocotyledonous plants	5	0

TABLE 7. Number of plants/m^2 and % ground cover of sown species and volunteer cereals in the first two years of permanent set-aside experiment.

Site	Date Assessed		Cover: / Cutting regime: / Mowings:	PRG 1 in situ	PRG 2+ in situ	PRG/WC 2+ in situ	PRG/WC 2+ removed	Nat Reg 1 in situ	Nat Reg 2+ in situ	Arable	SED
Boxworth (33 d.f.)	24/4/90	Bare ground	%	10.08	9.37	11.33	10.75	34.96	43.17	10.29	4.99
		PRG	%	34.33	36.17	30.96	30.83	.79	0.00	1.79	4.59
		Cereals	%	45.92	46.21	44.87	45.41	49.54	46.66	52.83	NS
		White clover	$/m^2$	.04	0.00	1.58	2.75	0.00	0.00	0.00	.77
	13/11/90	PRG	%	74.62	80.79	76.21	67.21	.04	0.00	0.00	4.79
		Cereals	%	5.96	.21	.04	.12	65.87	2.92	6.88	4.21
		White clover	$/m^2$	0.00	0.00	14.67	91.42	0.00	0.00	0.00	NS
	13/11/91	Bare ground	%	1.54	15.33	8.42	6.62	5.33	23.71	82.58	5.20
		Trash	%	14.54	8.54	7.29	4.67	79.75	48.17	12.12	6.10
		PRG	%	83.87	75.87	52.46	31.46	.04	11.75	.29	8.97
		Cereals	%	0.00	0.00	0.00	0.00	10.17	1.58	4.96	1.70
		White Clover	%	0.00	0.00	31.79	56.58	1.12	0.00	0.00	7.89
		Number of other species		1	1	1	2	5	9	1	
Bridgets (33 d.f.)	16/5/90	Bare ground	%	17.00	18.90	11.70	18.30	54.10	39.00	14.20	7.27
		PRG	$/m^2$	142.80	149.40	128.80	160.50	0.00	0.00	0.00	12.72
		Cereals	$/m^2$	51.00	58.00	45.70	51.20	55.70	48.70	91.70	NS
		White clover	$/m^2$	0.00	0.00	312.00	513.00	0.00	0.00	0.00	58.00
	26/10/90	PRG	$/m^2$	142.20	151.80	161.80	305.00	0.00	0.00	0.00	39.12
		Cereals	$/m^2$	0.00	0.00	0.00	0.00	11.70	3.10	19.50	12.62
		White clover	$/m^2$	8.00	0.00	1214.00	3731.00	0.00	1.00	0.00	257.00
	23/8/91	Bare ground	%	5.80	8.00	.80	1.90	1.70	.30	21.90	NS
		PRG	$/m^2$	129.80	160.30	131.50	174.50	6.80	14.20	1.00	16.47
		Cereals	$/m^2$	.33	0.00	0.00	0.00	19.50	0.00	0.00	3.47
		White Clover	$/m^2$	30.00	456.00	840.00	1523.00	0.00	964.00	0.00	278.30
		Number of other species		13	13	4	2	22	23	11	
Drayton (30 d.f.)	2/5/90	Bare ground	%	29.40	31.20	27.20	13.90	61.80	75.20	22.10	10.15
		PRG	$/m^2$	31.42	31.67	37.33	53.50	0.00	.08	0.00	4.57
		Cereals	$/m^2$	39.20	37.10	34.70	27.70	38.10	24.70	77.90	8.30
		White clover	%	0.00	0.00	1.00	1.17	0.00	0.00	0.00	.15
	22/10/90	PRG	%	64.75	67.75	72.25	75.00	.25	0.00	0.00	3.92
		Cereals	%	0.00	0.00	0.00	0.00	14.37	.75	5.25	3.50
		White clover	$/m^2$	0.00	0.00	10.60	26.50	0.00	0.00	0.00	NS
	17/9/91	Bare ground	%	5.60	12.10	9.87	6.90	4.52	16.87	84.15	4.51
		Trash	%	80.60	55.70	52.80	54.50	76.60	44.80	15.80	6.83
		PRG	%	13.70	32.15	26.05	21.97	0.00	0.00	0.00	4.36
		Cereals	%	0.00	.03	.03	0.00	.03	.35	0.00	.06
		White Clover	%	0.00	0.00	11.15	16.62	0.00	0.00	0.00	3.84
		Number of other species		0	1	2	0	15	18	0	
H Mowthorpe (36 d.f.)	12/5/90	PRG	%	40.83	38.33	37.08	38.96	0.00	0.00	0.00	2.41
		Cereals	$/m^2$	22.60	27.80	24.80	22.70	78.60	80.70	0.00	8.72
	12/9/90	PRG	%	65.83	56.87	42.50	43.33	0.00	0.00	0.00	3.18
		Cereals	$/m^2$	0.00	.04	.13	0.00	.33	3.25	0.00	.44
		White clover	%	0.00	0.00	33.96	29.27	0.00	0.00	0.00	3.51
	22/10/91	Bare ground	%	11.25	19.79	5.00	14.37	15.21	25.42	100.00	3.91
		Trash	%	34.58	28.96	15.21	11.96	57.08	40.62	0.00	4.89
		PRG	%	54.58	51.25	47.71	39.29	0.00	0.00	0.00	3.98
		White Clover	%	0.00	0.00	32.50	34.37	0.00	0.00	0.00	1.96
		Number of other species		0	0	0	0	9	9	0	

In both experiments perennial species had begun to appear by the end of the first year, but were still in relatively low numbers. However, they have already increased in the permanent experiment in some treatments, especially natural regeneration. It appears that these will reach significant levels by the end of the 5 year set-aside period on natural regeneration treatments but have been well suppressed by sown plant covers.

Effects on weed levels in subsequent crops

In no phase of the rotational experiment have undue weed problems occurred in the following test crops of wheat. However, it must be remembered that all treatments were managed so as to minimise seed production. The number and frequency of species recorded are given in Table 5. These recordings were made in unsprayed areas and it can be concluded that if the plant cover is not allowed to seed, there is no effect on weed levels or subsequent herbicide requirement in following crops. Perennial species have not been a problem in the rotational experiment but they have built up in the permanent experiment. It can be expected that perennial species will be important after longer term set-aside or if a field already infested with perennial species were set-aside on a rotational basis.

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FACTORS AFFECTING THE PLANT COVER DEVELOPING ON 5-YEAR SET-ASIDE AT ALDROUGHTY FARM, ELGIN

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ABSTRACT

In a series of experiments still in progress, various management treatments are being applied to 5-year Set-aside at Aldroughty Farm, Elgin. Compared with the variation attributable to uncontrolled environmental factors, most of the management treatments have had little effect on the species composition of the plant cover. In particular, the interim results suggest that it is unimportant whether the vegetation is cut in high summer or in early autumn, and whether or not the clippings are removed. The results also suggest that some Set-aside might rapidly become woodland were the requirement to cut discontinued.

INTRODUCTION

It was clear from the start of the Set-aside scheme that the management of 5-year Set-aside was going to be a factor in determining how its plant cover developed. Accordingly, experiments to study the effects of different managements were set up at a number of sites across the UK. This paper reports interim results from the most northerly experimental site; Aldroughty Farm, Elgin.

MATERIALS AND METHODS

Aldroughty is a 44.4-ha farm situated two miles west of Elgin (National Grid reference NJ1862) in a low-lying area (*c.* 30-m above sea level) with a mild, dry climate (mean annual rainfall *c.* 625 mm). In 1988 a number of contrasting areas on the farm were placed in 5-year Set-aside and experiments to study vegetation development under different managements were established at three locations.

<u>Fields 6 and 10</u>

A 400-m x 25-m strip of Set-aside adjacent to the bank of the Mosstowie Canal is being used to study 'natural regeneration' on a fertile alluvial soil not prone to drought. In a thrice-replicated experiment each block contains three randomly-arranged 25-m x 28-m plots; one plot cut once annually in June or July ('summer cut'), one plot cut once annually in late September ('autumn cut') and one plot cut twice annually, in summer and in autumn. The plots are cut using a finger-bar mower. Each plot is divided in half and every time a plot is cut the clippings are shortly afterwards removed from one half ('clippings removed' treatment), whilst the clippings on the other half are left *in situ* ('clippings left' treatment). The clippings removed/left treatments were allocated to the two halves of each plot on a random basis.

Field 14

The whole of this 0.89-ha field is in Set-aside. It is being used to study natural regeneration on a drought-prone loamy sand soil. It was selected as an experimental site because there were many trees nearby to act as seed parents; the northern edge of field 14 abuts onto mature mixed woodland, to the south only a road separates it from a wooded knoll.

In this experiment there are six blocks, each of three 30-m x 10-m plots. At the start of the experiment in October 1988 three of the blocks were surface cultivated with a spring-tine cultivator. Since then, one plot per block has been cut once annually in summer, one plot per block has been cut once annually in autumn and one plot per block has been left uncut. All those plots which are cut are divided in half and the clippings are removed from one half. The summer cut/autumn cut/uncut treatments were randomly-allocated within blocks and the clippings removed/clippings left treatments were randomly-allocated within plots.

Since the autumn of 1990 the amount of rabbit grazing on this field has been greatly reduced by a new fence.

Field 15

This 0.4-ha field is being used to study the vegetation developing on Set-aside sown in 1988 with a 50:50 (by seed number) *Lolium perenne-Trifolium repens* mixture. There are six blocks in the experiment and each block contains three randomly-arranged 20-m x 5-m plots. One plot per block is cut once annually in summer, one plot per block is cut once annually in autumn and one plot per block is cut twice annually, in summer and in autumn. As in the other two experiments, the clippings are removed from one half of each plot (Figure 1).

Field 15 is adjacent to field 14 and the soil in the two fields is similar. However, field 15 has remained unfenced.

In all three experiments the cover-abundance of the different plant species in the different plots has been recorded using the Domin scale (McVean and Ratcliffe 1962). The estimates are made immediately before the summer cut. In field 14, 150 1-m^2 permanent quadrats are used, five quadrats in each uncut plot and ten in each cut plot, five in each half. In the other two experiments, the cover-abundance estimates made in 1991 were for the whole area of each half-plot. Statistical analyses of the 1991 data were carried out using Genstat 5 (Lawes Agricultural Trust, Rothamsted Experimental Station, Harpenden, Hertfordshire, AL5 2JQ). Where comparisons between plots, half-plots or quadrats were made by calculating similarities from Domin cover-abundance scores, the Ecological test (test=4 in the fsimilarity directive) was used. Principal coordinates analyses were used to identify patterns within similarity matrices.

RESULTS

From the start of the experiments there have been major differences between the vegetation of the Set-aside at the three experimental sites. Domin scores for the most abundant species at each site in the summer of 1991 are shown in Table 1.

TABLE 1. Plant cover at the three experimental sites in 1991; Domin scores for the six most abundant species. The values shown are means of all the separate cover-abundance estimates made at each site.

Fields 6 and 10		Field 14		Field 15	
Arrhenatherum elatius	8.9	*Poa annua*	4.4	*Trifolium repens*	8.7
Cirsium arvense	4.4	*Holcus lanatus*	3.3	*Lolium perenne*	7.6
Dactylis glomerata	3.8	*Agrostis gigantea*	2.5	*Elymus repens*	2.3
Epilobium ciliatum	3.4	*Crepis capillaris*	1.9	*Crepis capillaris*	2.2
Holcus lanatus	3.3	*Epilobium ciliatum*	1.9	*Veronica arvensis*	2.2
Poa pratensis	2.8	*Cirsium vulgare*	1.9	*Cerastium fontanum*	2.1

Fields 6 and 10

The Set-aside here is now a summer-tall (up to *c.* 1.5 m) species-poor *Arrhenatherum elatius-Dactylis glomerata* grassland. Most of the species present are usually found growing in ruderal habitats or as arable weeds (e.g. *Tripleurospermum inodorum*), though some are more characteristic of long-established grasslands (e.g. *Deschampsia cespitosa*, *Lathyrus pratensis*). A preliminary analysis of the species-by-species cover-abundance data from July 1991 suggests that the vegetation which had by then developed under the six different experimental management treatments at this site was of similar species composition.

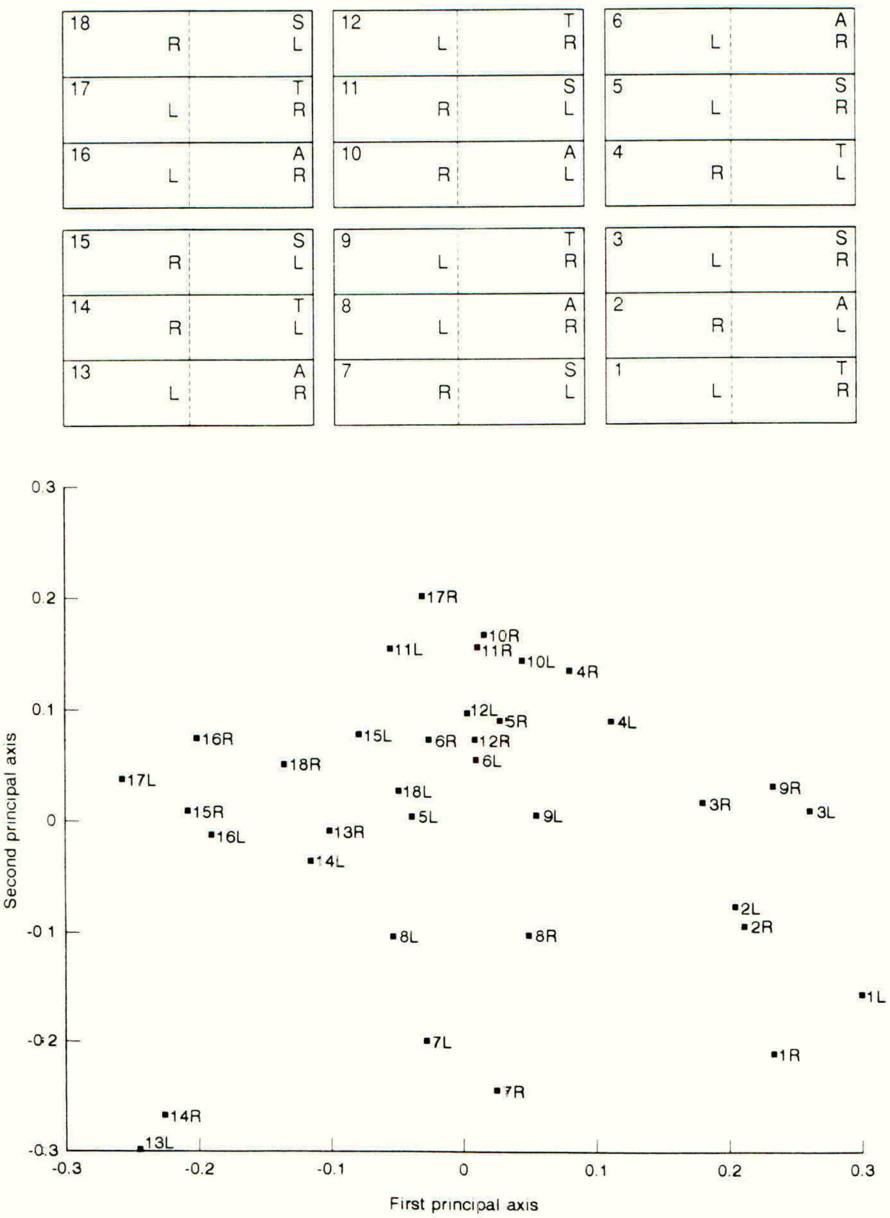
Field 14

The current plant cover on field 14 is far from uniform. Along the southern edge of the field and in its south-west corner is an area of *Arrhenatherum elatius* grassland. Species found here include *Elymus repens*, *Galium aparine* and *Urtica dioica*. In the centre of the field the vegetation, apparently affected by summer-time water shortages, is generally < 30-cm tall and gappy. This area is relatively species-rich and both weedy and grassland species are present. *Agrostis gigantea*, *Crepis capillaris*, *Hypochaeris radicata* and *Rumex acetosella* are all abundant. An area in the north of the field has been polluted by nutrient-enriched water overflowing from a nearby soak-away. Productivity is higher here than elsewhere in field 14 and the vegetation consists mainly of weedy and ruderal species (e.g. *Cirsium vulgare*, *Poa annua* and *Ranunculus repens*).

In a principal coordinates analysis of the data on plant cover collected in 1991, the quadrats did not group according to management treatment. Instead, there were three groups; the quadrats from the polluted area, the quadrats from the *Arrhenatherum elatius* grassland and the quadrats from the rest of the field.

Before the erection of the fence in 1990, field 14 was very heavily grazed by rabbits. Since the field was fenced, the height of the vegetation has greatly increased and seedlings of five tree species (*Acer pseudoplatanus*, *Fagus sylvatica*, *Fraxinus excelsior*, *Pinus sylvestris* and *Ulmus glabra*) have been found growing on

FIGURE 1. Above, the layout of the experiment in field 15, and, below, a scatter diagram of the half-plots from the principal coordinates analysis of the data on plant cover collected in 1991. Note that the position of the half-plots in the field and their position on the scatter diagram closely correspond, suggesting that east-west and north-south environmental gradients were the main causes of the differences between the half-plots. The half-plots are identified by the plot number (shown in the top left-hand corner of each plot in the upper diagram) and by an 'R' (clippings removed) or an 'L' (clippings left). On the plan of the layout of the experiment, shown in the top right-hand corner of each plot is whether that plot is cut in summer ('S'), in autumn ('A') or in summer and in autumn ('T').



the experimental plots. Seedlings of *Acer pseudoplatanus* are the most abundant and these reach a density of > 1 m^{-2} in the south-east corner of the field. There are very few tree seedlings in the centre of the field.

Although the principal coordinates analysis did not group together the quadrats from the uncut plots, in the block with the greatest density of tree seedlings the woody vegetation of the uncut plot was by 1991 noticeably distinct from that of the two cut plots. Many *Acer pseudoplatanus* on the uncut plot exceeded 60 cm in height, and this species' mean Domin cover-abundance score in the quadrats recorded on this plot was 3.6. The Domin score for *A. pseudoplatanus* did not exceed 2 in any quadrat recorded on either cut plot.

Field 15

Field 15 has remained as a *Lolium perenne-Trifolium repens* sward with few other species exceeding 5% cover in any plot.

Sixty vascular plant species were recorded in this field in 1991, most being common arable weeds (e.g. *Elymus repens*, *Poa annua*). Compared with field 14, the vegetation on field 15 was very uniform. What variation there was was not associated with the experimental management treatments; a principal coordinates analysis suggested east-west and north-south environmental gradients were the main causes (see Figure 1). The precise environmental factors involved here are not clear but the adjacent piggery may have locally increased soil fertility and there was some evidence that rabbits were most active on plots 1-3 and 7-9. It was noticeable that *Urtica urens* only grew vigorously on the otherwise bare soil around rabbit scrapes, while the abundance of other species may have been affected by rabbit grazing.

DISCUSSION

It is clear from the variation within and between the Aldroughty experimental sites that many factors can influence the vegetation which develops on 5-year Set-aside. The vegetation of field 14 alone has evidently been affected by the availability of mineral nutrients, the presence of rabbits and the nearness of trees. A comparison between the two unsown areas of Set-aside, one, in fields 6 and 10, on an alluvial soil and the other, field 14, on a loamy-sand soil, underlines the importance of edaphic factors in determining both the species composition and the productivity of the plant cover.

Of greater interest to policy-makers is the degree to which the various experimental managements have also affected the vegetation of the Aldroughty Set-aside. A comparison of the plant cover on field 15 with that on field 14 shows that sowing a cover crop has had a great and lasting effect. In contrast, the timing and frequency of cutting and whether or not the clippings are removed has so far proved unimportant. But on field 14 where there is a significant seed rain from the nearby trees it appears likely that the vegetation of the cut and uncut plots will soon be markedly different. Assuming that field 14 is not returned to agriculture and that the present management treatments are continued, the uncut plots seem to be destined to become woodland. It may be that if the present cutting requirement was dropped, woody vegetation would rapidly develop on 5-year Set-aside wherever there are trees close at hand, few deer and few rabbits.

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THE IMPACTS OF MOWING AND SOWING ON WEED POPULATIONS AND SPECIES RICHNESS IN FIELD MARGIN SET-ASIDE

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ABSTRACT

We examine the extent to which the need to control weeds on set-aside land and the desire to enhance species diversity for wildlife conservation conflict. A randomised complete block experiment on fallowed arable field margins was used to measure the development of diversity and the response of pernicious annual and perennial weeds to management. Swards were developed either by natural regeneration or by sowing, and managed by a range of simple cutting regimes. In sown swards annual weeds were eliminated rapidly and rhizomatous perennials established only at low frequencies. Naturally regenerated swards presented greater weed control problems. Mowing regimes which take account of the weed species' phenologies can be effective but no management at all is preferable to badly-timed mowing. Regimes that encouraged annual grass weeds also resulted in the highest species richness. Where weed control is considered important, mowing regimes should initially be timed to control the key weed species and only later relaxed to promote the development of diversity.

INTRODUCTION

The acceptability of the UK Set-Aside Scheme to many farmers and landowners has been limited by both real and perceived problems of pernicious weed control. The scheme has also been severely criticised by those interested in wildlife conservation and environmental enhancement because the management prescription (Anon 1988) seemed unlikely to allow the development of a diverse flora and associated fauna. Since the 1950's, agricultural weed control techniques have been incompatible with diversity. However, on set-aside land, which must be managed by mowing, relatively minor modifications to the current prescription might achieve both an acceptable level of weed control and a relatively rich flora.

We describe an experiment to examine the effects of a range of simple mowing regimes on the parallel development of diversity and of pernicious weed populations in both naturally regenerating and sown swards on 2m wide strips of fallowed arable land at edges of fields. Weed populations are likely to be higher in this situation than further into the field (Marshall 1989) but the potential for colonisation by non-weedy species will also be greater.

We concentrate on the results for the most common pernicious annual grass weeds of cereal crops (Froud-Williams & Chancellor 1982), *Bromus sterilis*, *Alopecurus myosuroides* and *Avena* species (*A. fatua* and *A. sterilis* subsp. *ludoviciana* combined), and on two perennials, *Cirsium arvense* and *Elymus repens*.

METHODS

In autumn 1987 we created 2m wide boundary strips (*sensu* Greig-Smith 1986) around six arable fields at the Oxford University Farm, Wytham. The strips comprised the original boundary strip (the 'old' margin) which was usually about 0.5m wide, and a fallowed extension of about 1.5m onto cultivated land (the 'new' margin). We established swards on the new margins either by allowing natural regeneration or by sowing a mixture of wild grasses and forbs (we refer to these as 'unsown' and 'sown' swards). The new margins were rotavated in March 1988 just before the seed mixture was sown. The mixture contained six 'non-aggressive' species of grass and 17 forbs in a 4:1 ratio, and was sown at 30 kg/ha. 50m long plots were established on both of these sward types and subjected to the following management regimes: uncut, or cut (with cuttings removed) in (a) summer only (b) spring and summer or (c) spring and autumn. Two further treatments were imposed on unsown plots only: (a) cut in spring and summer with hay left lying and (b) uncut but sprayed with glyphosate in late June. The plots were first cut in June 1988 and in subsequent years in the last weeks of April, June and September ('spring', 'summer' and 'autumn' respectively). Glyphosate (3 l/ha Roundup in 175 l water) was first sprayed in 1989.

These ten treatments were randomised in six complete blocks, each occupying a single field. The relative frequencies of plants colonising the new margins were monitored five times a year by recording presence/absence in eight sub-cells in each of three 50 x 100 cm permanent quadrats in each plot. We present monitoring results for June 1987, prior to establishment of the experiment, and for June of the next three years. These data were collected prior to the summer cutting and the spray treatments. In June 1989, 1990 and 1991 we also recorded the panicle densities of *B. sterilis*, *A.myosuroides* and *Avena* species in the permanent quadrats.

Significance levels are from two-way analyses of variance performed, for individual monitoring rounds, on mean densities or frequencies per plot, appropriately transformed to achieve homogeneity of variance. The Student-Newman-Keuls test was used for comparisons between treatment means.

RESULTS AND DISCUSSION

Avena species were abundant in all treatments in the first year after fallowing (Fig. 1). By the second year they had declined substantially in most treatments. They appeared to be unable to compete successfully in perennial swards, persisting only at low frequencies and being virtually absent from the very dense, sown swards. There are two striking departures from this pattern. The decline was much slower in swards cut in spring and autumn. Under this regime, in unsown swards, frequencies in 1989 and 1990 were significantly higher than in all other treatments ($P<0.001$). This regime also harboured a residual population *Avena* in sown swards. The openness of these swards in winter appears to promote germination and establishment. Although cutting in summer removed a high proportion of developing panicles (see Watt *et al.* 1990) it did not significantly affect population size in subsequent years. Controlling the germination and establishment of this species is a more effective strategy than controlling seed production because the population is buffered by a large, persistent seed bank. *Avena* species also remained relatively common in the low competitive environment of the sprayed plots, with a five-fold increase in density between 1990 and 1991.

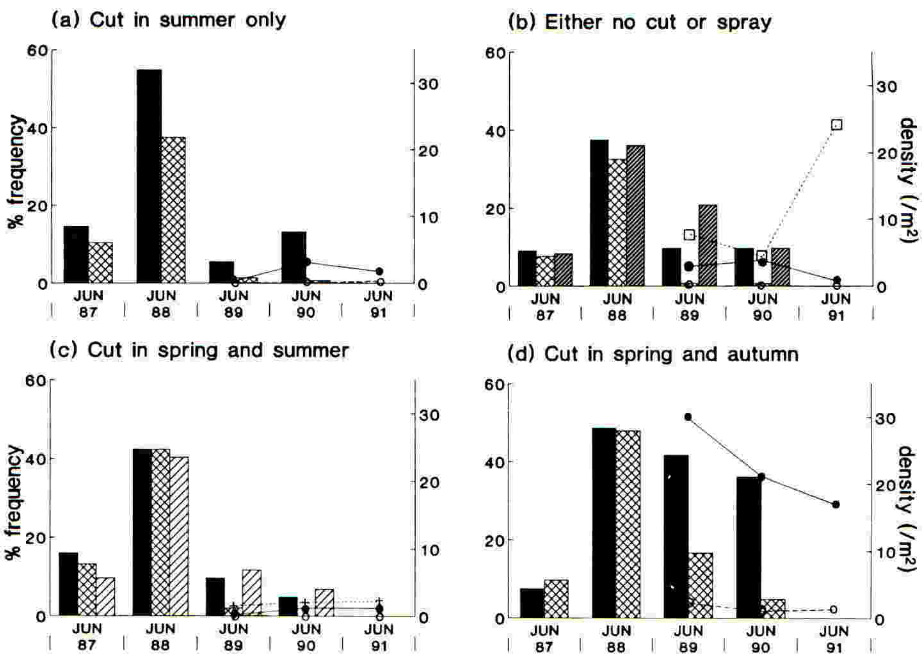

FIGURE 1. Change in abundance of *Avena* species 1987-1991
Bars represent frequencies and lines densities in unsown (■,—●—), sown (▩, --o--) and sprayed (b only: ▩,--□--) plots, and in plots where hay was left lying (c only; ▨, ---+---).

A. myosuroides was less common and more patchily distributed than *Avena* species but showed very similar changes in abundance (data not presented). It was very common in 1988, declined very substantially by 1989, and was then virtually absent from the sown treatments. Cutting in spring and summer appeared to result in the most rapid decline, as long as the hay was removed. Seeds of this species were ripening at the time of the summer cut and seed input would have been much reduced by hay removal. Spraying allowed *A. myosuroides* to persist at high levels, with densities increasing over 11-fold between 1990 and 1991.

In contrast to the previous two species, *B. sterilis* was uncommon in the first year of the experiment (Fig. 2). Rotavating the plots in March destroyed seedlings of this strictly autumn-germinating species. By 1989 its frequency had increased dramatically in unsown swards with a much smaller increase in sown swards (sown vs. unsown $P<0.001$). It remained common in unsown swards but decreased in sown swards, from which it was virtually eliminated by 1991. Its persistence in perennial-dominated swards is likely to be due to the ability of its seeds to germinate in the dark (Gray 1981). Our summer cutting regime was ineffective in controlling this early-flowering species although cutting in spring as well resulted in lower frequencies. As with *Avena* species, cutting in spring and autumn resulted in very high frequencies in 1990. The density data show that this pattern was accentuated by 1991.

The two perennial weed species increased in abundance more slowly than the annuals. In unsown swards, *E. repens* increased steadily to reach high frequencies by 1990 (Fig. 3). Within each cutting regime, frequencies were substantially lower in sown than in unsown swards in 1989 and 1990 (sown *vs.*

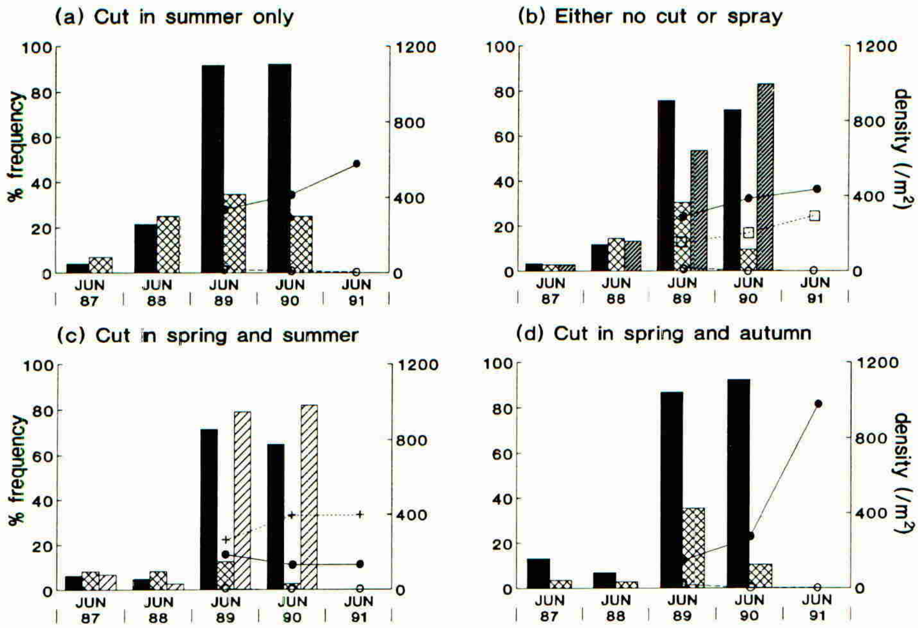

FIGURE 2. Change in abundance of *Bromus sterilis* 1987-1991.
Bars represent frequencies and lines densities in unsown (■, —●—), sown (, --o--) and sprayed (b only: , ···□···) plots, and in plots where hay was left lying (c only; , ···+···).

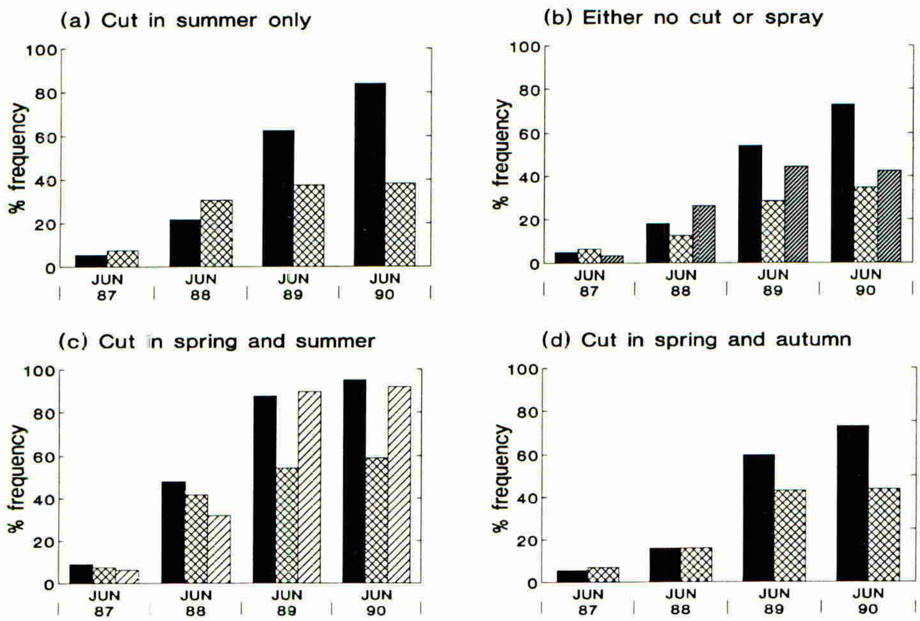

FIGURE 3. Change in abundance of *Elymus repens* 1987-1991.
in unsown (■), sown () and sprayed (b only:) plots and plots where hay was left lying (c only:).

unsown: $P<0.05$ and $P<0.001$ respectively). Frequencies did not increase in sown swards between 1989 and 1990 (see also Marshall 1990). Cutting in spring and summer, whether or not the hay was collected, resulted in the highest frequencies of *E. repens* amongst both sown and unsown treatments. In unsown swards both spraying and not cutting, resulted in the lowest frequencies. *C. arvense* was relatively uncommon and patchily distributed but like *E. repens*, it increased much more slowly in sown than in unsown swards (data not presented). Its frequency increased little or declined in most treatments on both sward types between 1989 and 1990. These rhizomatous species appear to compete most effectively in swards that are open during their main summer growth period.

By 1990 species richness remained higher in all treatments on sown swards than in those that were unsown (Table 1). Amongst both the sown and unsown groups of cutting treatments, cutting in spring and autumn resulted in the highest numbers of species. The sprayed treatment had least species. Both Simpson's and the Shannon-Weiner indices of diversity gave the same rank order of treatments as did species richness.

TABLE 1. Species richness in June 1990

Treatment	No. species ($/0.25m^2$)	Sig.[1] diffs.	No. sown species
Sown - cut in spring & autumn	17.0	a	(11.1)
Sown - cut in spring & summer	14.0	a b	(9.9)
Sown - not cut	13.7	a b	(9.7)
Sown - cut in summer only	13.0	a b c	(9.3)
Not sown - cut in spring & autumn	12.0	b c	
Not sown - cut in spring & summer	11.4	b c	
Not sown - cut in summer	11.2	b c	
Not sown - cut spring & summer, hay left	10.6	b c	
Not sown - not cut	10.2	b c	
Not sown - sprayed	9.4	c	

Treatment effect: $F_{(9,45)}=4.86$, $P<0.001$

[1] Means with the same letter are not significantly different

CONCLUSIONS

In the absence of appropriate management, common annual and perennial pernicious weed species can build up large populations on set-aside land. For most annual species these problems are likely to be short lived. They may nevertheless be visually unacceptable and, for species with long-lived seeds (e.g. *Avena* species), may create future problems if the land is returned to arable. Perennial weeds and *B. sterilis* present longer term problems, many of which can be solved by carefully applied, low intensity management. Sowing was more effective in controlling annual and perennial weeds than were any of our management regimes on unsown swards because it results in the rapid establishment of dense perennial cover. However, where mowing is carefully timed to interact with the germination and flowering phenologies of key weed species, it can bring substantial benefits. Equally, other badly timed mowing regimes can exacerbate weed problems: doing nothing is often preferable. Where annual weeds are a problem, spraying is the worst regime. Carefully timed herbicide applications can reduce populations of individual species but the simultaneous removal of the perennial cover ensures perpetuation of a weedy, annual-dominated sward.

It may be difficult to optimise a management regime for weed control when several weedy species present problems. However, our results suggest much more major conflicts of interest between management for weed control and for species diversity. The clearest example of this is the success of the spring and autumn cutting regime for the development or maintenance of diversity and its failure as a mechanism for annual grass weed control. This problem can be solved by creating 'artificial' diversity by sowing seed mixtures. This solution is likely to be desirable in many agricultural situations where the local flora is so impoverished that natural regeneration could never restore a rich flora (Smith & Macdonald 1989). However, where the aim is to exploit the regenerative potential of a relatively rich, local flora, seed mixtures should not be used because they exclude the desirable, as effectively as the undesirable, species. In these situations, cutting regimes that control severe weed problems, may have to take precedence over those that maximise diversity, at least until the weed problem is diminished.

ACKNOWLEDGEMENTS

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CHANGES IN THE SPECIES COMPOSITION OF A NATURAL REGENERATION SWARD DURING THE FIVE YEAR SET-ASIDE SCHEME.

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ABSTRACT.

Set-aside on a traditional heavy land cereal site resulted in a sward dominated by Elymus repens (common couch grass). Dominance was achieved through competitive exclusion and the sensitivity of the other principal species present (which were annual grasses) to the new management regimes based upon cutting. Most sensitive was volunteer wheat, followed by Alopecurus myosuroides (blackgrass). Bromus sterilis (sterile brome) was most difficult to control under the new conditions.

INTRODUCTION.

The introduction, in 1988, of a set-aside scheme for arable land (MAFF, 1988) highlighted some gaps in the knowledge of the behaviour of certain species associated with arable crops. Knowledge of their response, in terms of competitive ability, regrowth and seed production when mown as a grassland was largely theoretical based upon subjective and observational evidence. This paper is a report on a project initiated in 1987 to investigate the topic of cost-effective weed control for set-aside land, which has contributed to some of the questions raised above.

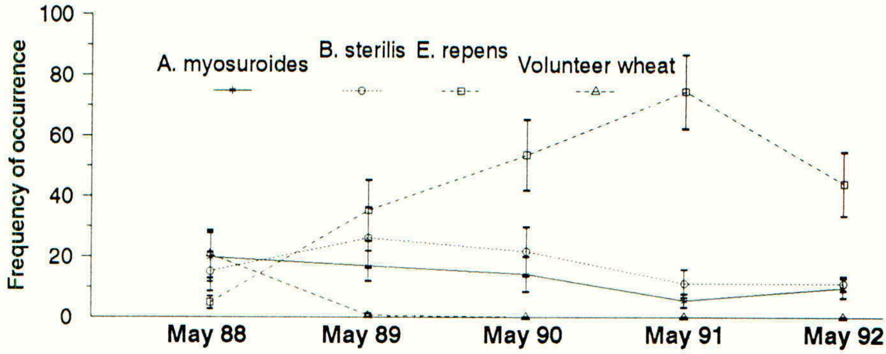
METHODOLOGY.

The principal experiment lay on a calcareous gley (Burwell series) on the Bedfordshire / Hertfordshire border. This experiment was of a randomised block design, with four replicated blocks of treatments. Plot size was 7.8 m by 20 m. The field had previously grown 4 crops of winter wheat. Three cutting regimes were imposed upon the naturally regenerating sward. A frequent mowing regime, involving 3 to 5 cuts per year, and two less frequent regimes (2 or 3 cuts/year), one of which involved the removal of the cuttings. In the first two years of the experiment (1988 & 1989) additional plots were cultivated or sprayed. This paper considers the results of the cutting treatments.

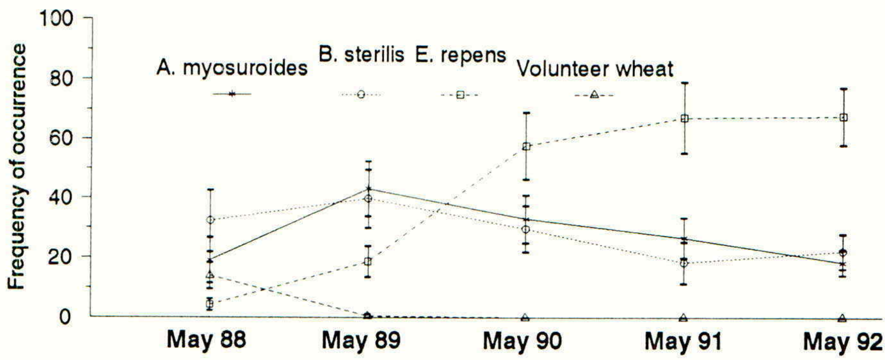
Species composition was recorded annually (in May) by counting the frequency of occurrence of each species in the 100 subdivisions of a $1m^2$ quadrat. Ten quadrats were placed in each plot, at the same point each year. Each week during year 2 (1989), sward heights were recorded by measuring maximum height of a large number (50 per plot) of tillers of B. sterilis, and flower head counts were made in 10, $1m^2$ quadrats placed

FIGURE 1. The frequency of occurrence of the principal species present.

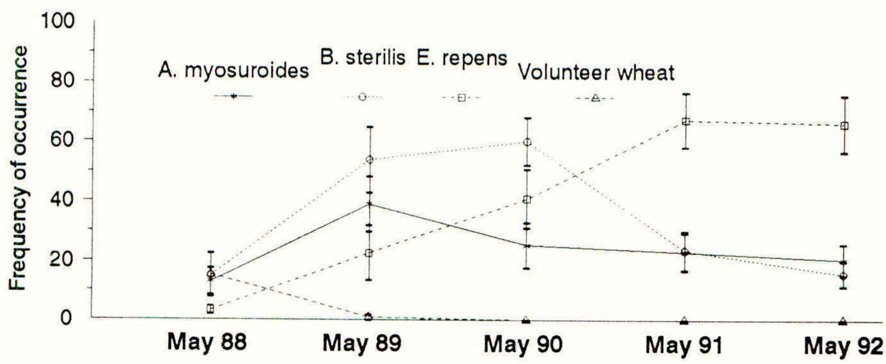
a). Frequent cutting (3 - 5 times per year).



b). Infrequent cutting (2 - 3 times per year).



c). Infrequent cutting, cuttings removed.



95% Confidence interval included

randomly.

The soil seed bank was evaluated using a method based upon Graham and Hutchings (1988). This involves germination of the soil seed bank in controlled conditions. Soil samples were taken from within the above permanent quadrats (2 per quadrat) to a depth of 20mm, at the times referred to in Figure 3. This gave a sample mass of approximately 1.5 kg, which was sub-sampled to give a 0.5 kg (dry mass) sample for testing in the greenhouse. Results were converted to No. seeds/m^2 using the dry bulk density (mean of 1.1 g/cm^3).

RESULTS AND DISCUSSION.

The first year of Set-aside was dominated by annual grasses such as Bromus sterilis (sterile brome), Alopecurus myosuroides (blackgrass) and volunteer wheat (see Figure 1). The most striking change in frequency of occurrence from year one (1988) to year two (1989) was, the reduction in volunteer wheat, and the increase in E. repens. The other grasses generally increased as bare ground was colonised. A. myosuroides was significantly reduced ($p < 0.001$) where the lower frequency cutting regime was practised. However, only B. sterilis increased significantly ($p < 0.001$), where the cuttings were removed. As cutting dates were the same for both low frequency cutting regimes in 1988, it is possible that this is due to the presence of surface litter.

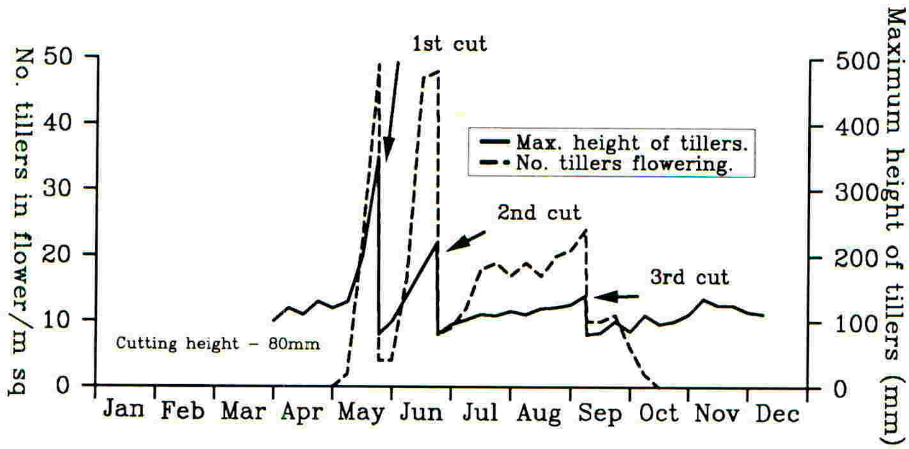
In the succeeding years the annual grasses (A. myosuroides and B. sterilis) were gradually suppressed. This is largely due to a better understanding of their physiology leading to better timing of cuts. The effect of treatment upon the degree of suppression was not significant. The reduction in A. myosuroides frequency of occurrence from year one to two where cutting was most frequent, lead to it occurring consistently (and significantly) less frequently than where cutting was less frequent. The increase in E. repens frequency of occurrence continued into years 3 and 4 but it was suppressed by frequent mowing in 1991, to leave the significant difference ($p < 0.001$) from the less frequent mowing regimes, observed pre-cutting in 1992.

The physiological basis for the changes observed.

Figure 2. shows the response of B. sterilis to mowing over the year 1989 (second year Set-aside). The data relates to low frequency mowing, cuttings returned. The same physiological response was observed in the other treatments. The height of flower heads was particularly low when B. sterilis was growing at low densities (ie. < 10 tillers / m^2) and in the exceptional moisture stress of 1989 and 1990. Observations indicated that A. myosuroides and wheat also showed this response to cutting.

The reductions in flower height and numbers observed in A. myosuroides and B. sterilis were probably due to the large amount of energy required to produce an inflorescence. As much as 45% of stored photosynthetic assimilates can be required for stem elongation (Jones and Lazenby 1988). Mowing removes the principal meristems, photosynthetic area and apices. Early in the season A. myosuroides and B. sterilis recovered well after mowing. This was due to stem elongation in later developing tillers that where below cutting height at the time of mowing. However, volunteer wheat recovered from the first mowing only.

FIGURE 2. The growth of Bromus sterilis when mown infrequently .



E. repens was the only perennial present in the first year. A perennial has the competitive advantage over an annual in a permanent grassland situation. The establishment of a seedling is hindered by the presence of a relatively dense perennial plant cover. Further to this, the rhizome that E. repens produces acts as a store of photosynthetic assimilates, allowing rapid recovery of photosynthetic area after cutting, in contrast to the annuals which have been shown to be weakened by successive cuts. On the plots where cultivations or herbicides eliminated E. repens completely in 1988 and 1989 it has not, as yet (1992), re-colonised.

Cutting to control seed production by A. myosuroides and B. sterilis.

A. myosuroides exhibits a staggered ear emergence. A mid-May cutting date could encounter A. myosuroides tillers ranging from ear at 1 cm (GS31) to anthesis almost complete (GS57). The consequence of this in the field can be the rapid (4 days, May 5th - 9th 1989) re-emergence of flowers after mowing in May, some obviously damaged by the mower whilst emerging. These flowers can make good progress towards producing viable seed before a follow up cut.

Anthesis in A. myosuroides is highly visible, the exposed anthers give the ear a light brown colour. When they start to fall (beginning at the top and working down) anthesis is complete and the ears begin to take on their characteristic dark purple colour. Cutting must follow the end of anthesis relatively quickly. It is uncertain how long a period of endosperm production is required to produce viable seed. Physical disturbance of uncut plants on June 9th 1989 resulted in shedding, and collected seed germinated in the laboratory. It is possible that the earlier the cut the less endosperm production that will have taken place and the less vigourous the resultant seedling will be.

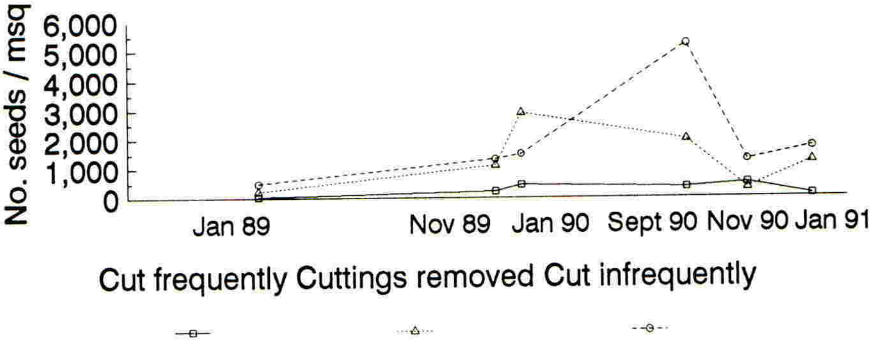
B. sterilis has been shown to self pollinate to a certain extent whilst the flowers are still enclosed within the flag leaf sheath. This means that for some of the florets all the of time post emergence is devoted to endosperm production. Froud-Williams (1983) recorded viable seed production in B. sterilis 7 days after the end of anthesis (GS 60).

Effects on the soil seed bank.

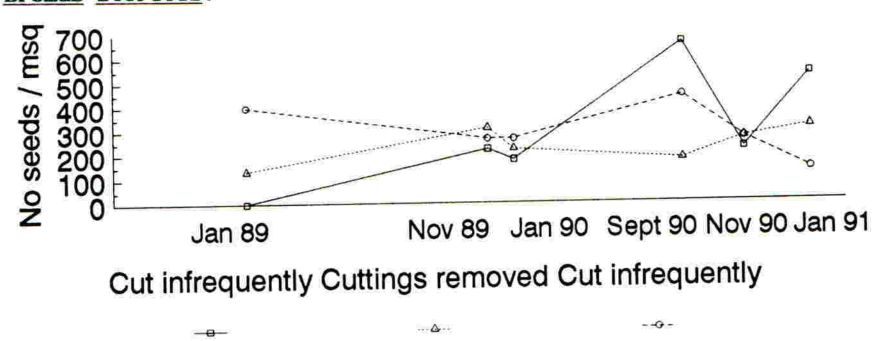
Frequent mowing produced a consistently smaller seed bank for A. myosuroides than either of the less frequent mowing regimes (Fig. 3a.). B. sterilis is known to show only minimal dormancy and therefore the soil seed bank was low (Fig. 3b.). Resources did not allow replicated assessment of the soil seed bank, preventing statistical analysis.

FIGURE 3. The soil seed bank (to 20 mm depth).

a). Alopecurus myosuroides.



b). Bromus sterilis.



Future arable cropping on the site.

E. repens poses a considerable threat to future crops. Control with glyphosate is possible, but the plant residue may prove a physical obstacle to cultivations and has the potential to harbour Gaeumannomyces graminis (the take-all fungus) and Fusarium spp. and Pseudocercosporella herpotrichoides (eyespot), which can cause significant yield and quality losses in cereals. Fungicides have minimal affect upon G. graminis and Fusarium, and only careful management in view of the potential threat can minimise the problems. The added threats of A. myosuroides and B.

sterilis in the soil seed bank, and the possibility of nitrogen lock-up by the soil organic matter after an unfertilized grass sward is broken (Hewitt 1990), lead to the recommendation that such a set-aside period be followed by a leguminous break crop such as beans. The herbicide options in such a crop give the opportunity for a year free from grasses, which will greatly reduce the threat to a wheat crop from soil borne disease and the soil seed bank.

CONCLUSIONS.

Volunteer wheat showed sensitivity to cutting in May. Regardless of treatment, very few plants survived mowing in the May of year 1.

Alopecurus myosuroides showed a sensitivity to cutting frequency, with reduced frequency of occurrence and soil seed bank size where more frequent mowing (>3 cuts/yr) was practised.

Bromus sterilis has demonstrated its versatility in completing seed production between cutting dates and below effective mowing height.

Elymus repens has shown itself to be best suited, of all the species present, to the set-aside situation, irrespective of treatments applied. Where it was eliminated, by herbicides or cultivations, it has not re-colonised.

The potential threat to a wheat crop from; i) soil borne diseases associated with E. repens, ii) a relatively large soil seed bank of A. myosuroides and B. sterilis and iii) possible nitrogen lock up by soil organic matter derived from the sward, lead to the recommendation that a leguminous break crop follows such a set-aside period.

ACKNOWLEDGEMENTS.

Mr W. Pickup (Farm Manager) and the Ashley Cooper family (owners) lent 0.8 ha of Hexton Manor Farm, Hexton. Votex Ltd. kindly lent a pasture topper and Ford New Holland kindly made available tractors. The work was funded by a MAFF scholarship.

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WEED CONTROL IMPLICATIONS OF THE RETURN OF SET-ASIDE LAND TO ARABLE PRODUCTION

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ABSTRACT

A number of surveys and trials throughout the UK have examined vegetational change on long-term (3-5 years) set-aside land. A review of some of this work is undertaken, and a clear trend from early dominance by annual species, and a succession through biennials to perennial species is evident. However, important annual grasses and biennial arable weeds can persist in open areas in unsown set-aside. The farmer with unsown set-aside will have to expect a residue of annual and biennial weed seeds plus seed and vegetative propagules of perennials. Most ensuing weed problems could be controlled eventually in cereal rotations, but may be much more difficult where broad-leaved crops, and particularly horticultural and perennial crops, are important. It is proposed that ploughing to invert the soil profile be used to bury the residue of weed seeds, and expose the older seedbank of 3-5 years ago. The farmer should then minimize cultivation for 2-3 years to allow some reduction in the buried seedbank. The use of soil inverting by ploughing followed by minimal cultivation may also be useful following one-year set-aside where there has been a large population of annual weeds. A combination of a glyphosate treatment followed by inversion by ploughing may be the best option where perennial weeds are also a problem.

INTRODUCTION

The current UK set-aside scheme was introduced for a period of 5 years, but with an option to leave the scheme at the end of 3 years, or in the form of a one-year rotation. Of clear interest is the likely impact of set-aside on weeds in future rotations, and how their impact can be minimised. It is also important to conservation interests to assess how easily land may be returned to agriculture without the excessive use of herbicides.

This paper reviews the results of trials and surveys on set-aside, a number of which are presented in these Proceedings, and evaluates the potential impact of the findings on the return to arable farming. Schematically, it describes the succession of flora noted by the workers, and then evaluates the likely impact of the contributors to the floral succession, in terms of annuals, broad-leaved biennials and perennials, perennial grasses and volunteer crops on the succeeding rotation, and how that might be controlled. Because of the effects on the seedbank all the components of the succession have an impact on the arable rotation, and not just the plants present at the point of return. The authors also acknowledge that the definition of a problem weed will vary, and many of the conclusions are of untested opinion.

RESULTS OF TRIALS AND SURVEYS

The workers reviewed noted a general succession on bare set-aside land of annuals, usually crop volunteers and common weeds in the first year (Clarke and Cooper, 1992). Biennials and perennials establish in the first two years and the perennials, particularly grasses, then become dominant over a four to five year period but with annuals and biennials still numerous. Woody species have also appeared. This is a classic pattern of succession.

Annuals

All authors have noted the rapid establishment of annuals during the first season of set-aside, which then diminishes over the set-aside period (Fisher and Davies, 1991; Rew et al., 1992; Wilson; 1992). Lawson, et al. (1992) note that these would have contributed considerably to the weed seedbank whilst bare ground was available. Most species are capable of the few years of survival required to contribute to the succeeding arable rotation although losses are to be expected; for example, due to surface predation (Lawson, et al., 1992). Some may not survive more than one or two years, eg. *B. sterilis*, *Poa annua*, but if bare land is available will produce plants on an annual basis. This has been noted in particular by Wilson (1992), who found *Bromus sterilis*, a major arable weed, increased in set-aside fields in a survey in S.E. England. Fisher, et al. (1992) found *Poa annua* present in 88 out of 113 surveyed fields in Tayside and Fife after three years, although Wilson (1992) noted a decrease in cover by this weed over time. Nevertheless; if bare ground is available, such annuals persist. Sowing set-aside with ryegrass or red fescue reduced *P. annua* in a Scottish trial (Fisher and Davies, 1991) and reduced cover from 8.9% to 0.14% of set-aside fields in a Scottish Survey (Fisher et al., 1992). Cutting regimes stipulated by the set-aside regulations do not give complete control over seed set. Clarke and Cooper (1992) indicated that frequent cutting of *Alopecurus myosuroides* and *Bromus spp* led to lowering of seed heads, but that production and shedding still occurred. The wide flowering window of annuals must also mean that there are species which miss the cuts.

Broad-leaved Biennials

Broad-leaved biennials have also been noted as establishing quickly in bare areas of set-aside (Fisher and Davies, 1991; Rew et al., 1992; Wilson, 1992), which is to be expected from earlier studies on succession (Gibson and Brown, 1991). *Epilobium spp*, *Senecio spp* and *Cirsium vulgare* and *Sonchus spp* are quoted most frequently. Lawson et al. (1992) suggest that their presence was not indicated by numbers in the initial weed seedbank at a Scottish site, and, in particular, *Senecio vulgaris* increase is probably explained by wind dispersal. Fisher et al. (1992) describe the presence of biennials as common in a Scottish survey, but Rew et al., (1992) and Wilson (1992) seem to indicate that these are more transitory in S.E. England. Nevertheless, these species will probably contribute to the seedbank of the arable rotation.

Broad-leaved Perennials

Scottish surveys indicate that broad-leaved perennials increased in importance with the age of the set-aside (Fisher et al., 1992), and this is confirmed by Rew et al. (1992) for S. England. Certain species persist in sown set-aside, unlike most annuals and biennials, although at lower numbers than in unsown set-aside (Fisher et al., 1992). Many of these persist by vegetative propagation, and will move into set-aside from field margins (Rew et al., 1992) but probably not more than a few metres in the time available. However, some also produce abundant viable seed (eg. *Rumex spp, Ranunculus repens). R. repens* has been noted as the commonest species colonizing Scottish unsown set-aside, along with *Trifolium repens*, and also occupyies the greatest area (15.7%) of any species (Fisher et al., 1992). This may be different from S.E. England where grass species always dominated a survey by Wilson (1992). Other species cited from surveys include *Chamerion angustifolium, Cirsium arvense, Bellis perennis, Urtica urens, Tussilago farfara* from Scotland and also *Glechoma hederacea, Heracleum spondylium, Primula veris, Ranunculus bulbosus* from S. English sites.

Perennial Grasses

Most fields surveyed have one or more perennial grasses present. Wilson (1992) states that one of *Agrostis stolonifera, B. sterilis, Elymus repens* or *Poa trivialis* was usually the dominant species. Fisher et al. (1992) also include *Holcus lanatus, Agrostis capillaris, Alopecurus geniculatus* and *Phleum pratense*, as common in their survey and one of us (D. Atkinson) has noted *Agrostis gigantea* as dominant in unsown plots in a trial in N. Scotland. Of course, sown fields are often dominated by *Lolium perenne*. All of these spread by vegetative propagation and by seed, and Rew et al. (1992) found that they decreased exponentially from field boundaries. They also noted *that Arrhenatherum elatius* and *Festuca rubra* colonized bare boundary areas.

Woody Perennials

A number of woody perennials have been seen in surveys, but in Scottish sites grazing by deer and rabbits has reduced establishment of tree species, although *Ulex europaeus* was establishing on some set-aside fields (Fisher et al., 1992). *Rubus species* may be doing the same. Nevertheless, there could be a weed seedbank build-up if there are trees and shrubs surrounding the set-aside, which could affect perennial crops and farm forestry.

Volunteer Crops

Clarke and Cooper (1992) have noted that volunteer cereals have persisted in one cut regimes for two years of set-aside. Potatoes and oilseed rape were also noted in Scottish surveys, but did not persist at high levels (Fisher et al., 1992). These could be a problem in following seed crops. There is less known about their importance in carrying over diseases and pests, but potato nematodes, clubroot and take-all levels may be affected. Various weed species can also be carriers of such problems, and grassy set-aside may also encourage other pests such as leatherjackets.

CONSEQUENCES FOR WEED CONTROL IN FOLLOWING CROPS

Annual and Biennial Weeds

The initial build-up of weed seeds, and in some cases, the persistence of annual and biennial species in bare spaces in set-aside, can have consequences for the arable rotation. Most of the weeds persisting, can be controlled by cereal herbicides available, but there could be an increased cost for certain weeds. Higher numbers may mean that higher rates or more complex programmes may be required. In the case of *B. sterilis*, and *A. myosuroides*, both serious arable weeds, good control is often difficult. Non-cereal crops have far fewer herbicide options than cereals, except possibly for grass weed control. In particular, horticultural crops may be severely affected by greatly increased weed seedbanks of both annuals and biennials.

Inverting by plough may provide a useful technique. Ploughing set-aside will present a seedbank of 3-5 years old to the surface which will have diminished over the set-aside period (Roberts, 1958). For the following two years, minimal cultivation would ensure that a proportion of the set-aside seedbank will not return to the surface. This will allow most species to diminish significantly, eg. *A. myosuroides*, and others to disappear, eg. *B. sterilis*, *P. annua*. Roberts (1958) found that two years of clean-cultivated vegetables reduced a weed-seed population to 19% of the original level. When deep cultivation restarts, then it should be maintained for the following seasons (Roberts, 1973).

Broad-leaved Perennials

There will remain both vegetative propagules and seed of these species. They can be a problem in cereal rotations, eg. *C. arvense*. Treatments are available, but timing can be a problem, as cereal crops are often past stem extension or first-node stage when products such as 2,4-D can be usefully used. Metsulfuron-methyl has an effect on small plants of *C. arvense* and *Rumex spp.* More seriously, perennial horticultural crops or a farm forestry development could be severely affected, and a number of species can be a problem in rotational and permanent grass, where herbicides are available, but may entail damage to clover components. Some species do not stand cultivation, but in other cases cultivation may spread vegetative propagules, eg. *C. arvense*. The use of a glyphosate product on the set-aside will control most of these species. Where they have spread from the field margin or from loci, then glyphosate could be targeted more carefully. It should be noted that many perennial species produce persistant viable seed, and, as in the case of annuals, inversion ploughing may assist longer-term control.

Perennial Grasses

Most perennial grasses quickly disappear under cultivation, but some will persist to become major weed problems; notably *E. repens* and *A. stolonifera*, and more locally *A. elatius*, *P. trivialis* and *P. pratense*. Any surviving cultivation can be effectively controlled pre- or post-harvest in following cereal crops with glyphosate. Seedlings may be controlled with a range of cereal herbicides such as isoproturon, or possibly, imazamethabenz, chlortoluron or diclofop-methyl on certain species (Table 1).

There is a greater problem going into broad-leaved crops, and perennial crops, where the graminicides available are often no more than suppressants of perennial grasses from vegetative propagules. However, cultivation to break up rhizomes will assist their control with graminicides available for broad-leaved crops (Table 1), and these gramincides will control seedling grasses. For these species, the use of glyphosate on set-aside looks the best option unless levels are low or and the farmer is going into a cereal break first.

TABLE 1. Major graminicides and perennial grass species recommended on labels as being controlled.

	Elymus rep.	Lolium per.	Poa triv.	Arrhen. ela.	Poa pra.	Agros. stol.	Agros. gig.
Cereal Crops+							
chlorotoluron	-	√	√	-	-	-	-
diclofop-methyl	-	√	√	-	-	-	-
imazamethabenz	-	√	√	√	√	-	-
isoproturon*	-	√	√	-	√	-	-
Broad-Leaved Crops°							
cycloxydim	√	-	-	-	-	√	√
quizalofop-ethyl	√	√	-	√	-	√	√
sethoxydim	√	-	-	-	-	√	√

\+ Seedlings only

* There are anecdotal claims of a wider range of seedling perennial grass weed control.

o Seedlings controlled; suppression of perennials, but chopping-up of rhizomes will assist in control.

Woody Perennials

These are unlikely to present a problem except where a perennial crop is being established; especially farm forestry. In this case spot treatment or roguing may be the only feasible options.

Volunteer Crops

They are often difficult to control, and impossible in similar crops. Volunteer crops should be controlled whilst in the set-aside when possible. In particular, volunteer potatoes could be treated with glyphosate but true potato seed may present problems. Ploughing to invert the soil, as suggested for some annual weeds, may assist in controlling cereals. However, anecdotal evidence indicates that oilseed rape (Lutman, 1991) and potato seed can persist for some time (Lawson, personal communication).

CONCLUSIONS

Build-up of the weed seedbank in set-aside may cause considerable problems in following crops, with an increased use and cost of herbicides. The best approach may be to use an inverting plough in the first instance to bury the set-aside seedbank, then use reduced cultivations for the next 2-3 years to allow the set-aside seedbank to diminish. This approach may also be preferable following one-year set-aside (rotational) where there has been a large population of annual weeds. Thereafter, a thorough cultivation programme may be preferable.

Certain perennial weeds, notably grasses, from vegetative propagules, probably present a greater problem, as they may survive cultivation. Where these are present the use of glyphosate on set-aside may be the preferred option, although there are other options in cereal crops. A combination of glyphosate treatment followed by inversion ploughing may be the best option in many situations.

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SPATIAL AND TEMPORAL VARIATION IN THE VEGETATION IN SET-ASIDE FIELDS AT CONINGTON, CAMBRIDGESHIRE

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ABSTRACT

Vegetation development monitored on a farm in set-aside showed that grasses increased in abundance with *Alopecurus myosuroides, Bromus hordeaceus, Bromus sterilis* and *Elymus repens* providing 87% of grass cover. These species were present from the first observations in the spring following set-aside; a restricted range of herbaceous dicotyledons was also recorded which increased in cover and diversity but at a slower rate. Although the pattern of recolonisation varied between fields this could not be related to recent cropping history. A greater diversity of species was present in the seed bank, particularly in soil from field margin sites. There was little correlation between the above ground vegetation and the seed bank. These results illustrate the importance of arable weeds, particularly grasses, in the set-aside vegetation.

INTRODUCTION

The soil physical properties associated with arable fields are maintained by continuous cultivations and create an optimal environment for growth of a range of plant species. Soil disturbance and applied herbicides limit unwanted weeds whilst inorganic nutrients create conditions where competition from the crop restricts the success of other plant species.

The changes introduced by set-aside might therefore be expected to result in rapid recolonisation by a wide variety of plant species, from vegetation at the field margins and the seed bank. Although sources of new recruits may be some distance from the field centre, The seed bank in arable fields can be very persistent and diverse. Cropping history will influence the weed flora and the seed bank, and although many species produce long-lived seeds, the seed bank will gradually decline if no new seeds are added. In addition, plant species which survive as part of the above ground weed flora of modern arable fields are likely to be both persistent and competitive when cultivation ceases. This study, which investigates the vegetation of set-aside fields in relation to cropping history, compliments a multi-site programme reported by Clarke & Cooper (1992) investigating vegetation changes and agronomic weeds in and after set-aside.

METHODS

The three fields examined form part of an investigation into the effects of set-aside on the hydrology, soil nutrient levels, and pesticide and nitrate leaching (Harris et al., 1992). The artificially drained site in East Anglia, U.K., located on predominantly brown calcareous clay soils, was in long term arable prior to set-aside. Under set-aside the vegetation was cut annually in July/August; residues were returned to the ground surface. The vegetation patterns were investigated from fields which supported winter wheat, spring wheat and field beans in the year preceding set-aside. In each field, nine $1m^2$ quadrats were established, with a further nine within 10m of the margins of the field previously in winter wheat. A photographic record, from May 1989, of the vegetation in these quadrats was used to provide percentage cover estimates for all species present. The vegetation in 2x2m adjacent quadrats was further surveyed in July 1991 and a subjective estimate of percentage cover of every plant species obtained at each station.

In addition, in the winter wheat field, soil samples were collected in October and November 1991, immediately adjacent to each quadrat and along a transect from the field margin. These consisted of three 4x200mm cores which were bulked prior to sampling. After sieving (2mm), 200g of air dry soil was either spread directly on moist peat substitute, watered and kept in a heated greenhouse to encourage seed germination or cold-treated for at least four weeks at 5^0C before germination. Emerging seedlings were identified.

RESULTS

Fig. 1 summarises the trends in vegetation cover for species, combined into three categories: crops, non-crop grass species and other plants (mostly herbaceous species). All fields show a similar pattern. In the early part of the first season (1989) crop volunteers dominated the vegetation; these declined over the next two seasons whilst grasses increased in dominance. Other plants also followed an increasing trend but their rate of increase in cover lagged behind that of the grasses. The field survey revealed that by July 1991 grass cover was virtually complete.

Four grass species, variable between fields, made up 87% of the grass cover. These were *Alopecurus myosuroides* (black grass), *Bromus hordeaceus* (soft brome), *B. sterilis* (barren brome) and *Elymus repens* (couch grass). In the former winter wheat field, *B. hordeaceus* was the most abundant species *A. myosuroides* was the most abundant grass in the former spring wheat and bean field. Amongst the other plants the most important was *Rumex crispus* (curled dock) which was common in the spring wheat field and increased over the survey period. A significant population of *Picris echioides* (bristly ox-tongue) was recorded in the winter wheat. Full details are reported by Gallagher (1992) and Noel (1992).

Table 1 shows the trends in species numbers and diversity for the centre and margin quadrats for each crop type preceding set-aside. All fields were characterised by relatively low species diversity. The number of species recorded in each field increased during the first months then fluctuated for the rest of the study. The last sampling was a field survey and this may partly explain the relatively high numbers recorded on this date. The diversity index did not follow the change in species numbers nor the increase in total abundance (Fig.1).

Almost twice as many species were identified from soil samples (39 species) than were recorded as components of the above ground vegetation (22 species). In the three years studied, *B. sterilis* and *B. hordeaceus* were consistently the most abundant species in the seed bank as they were in the above-ground vegetation. There was little correlation between the above ground vegetation and the seed bank (Spearman's Rank Correlation: centre = -0.05; margins = 0.51). Soil samples taken from the marginal sites contained more species (32 species) than samples from the centre (26 species) and a number of plants characteristic of hedgerows and headlands were present as seeds in the soil from the field edge (Hitchin, 1992). These species included: *Urtica dioica* (nettles), *Conium maculatum* (hemlock). *Arrenatherum elatius* (false oat grass, *Heracleum spondyllum* (hogweed) and *Anthriscus sylvestris* (cow parsley).

Table 1 The number of species and the Shannon-Wiener diversity index (H) for the mean % cover values since 1989.

Winter Wheat	Centre		Margin		Field Beans			Spring Wheat	
month/ year	No. of Species	H	No. of Species	H	month/ year	No. of Species	H	No. of Species	H
5/89	2	1.0	5	1.9	5/89	9	1.4	4	1.9
6/89	7	1.7	9	2.0	6/89	8	2.1	10	2.0
4/90	8	1.6	7	1.2	9/89	6	0.7	9	1.2
7/90	6	1.3	8	1.3	4/90	8	1.2	10	1.3
5/91	9	1.2	8	1.4	5/91	9	1.6	9	1.4
7/91	17	1.8	14	1.8	7/91	18	1.9	11	1.8

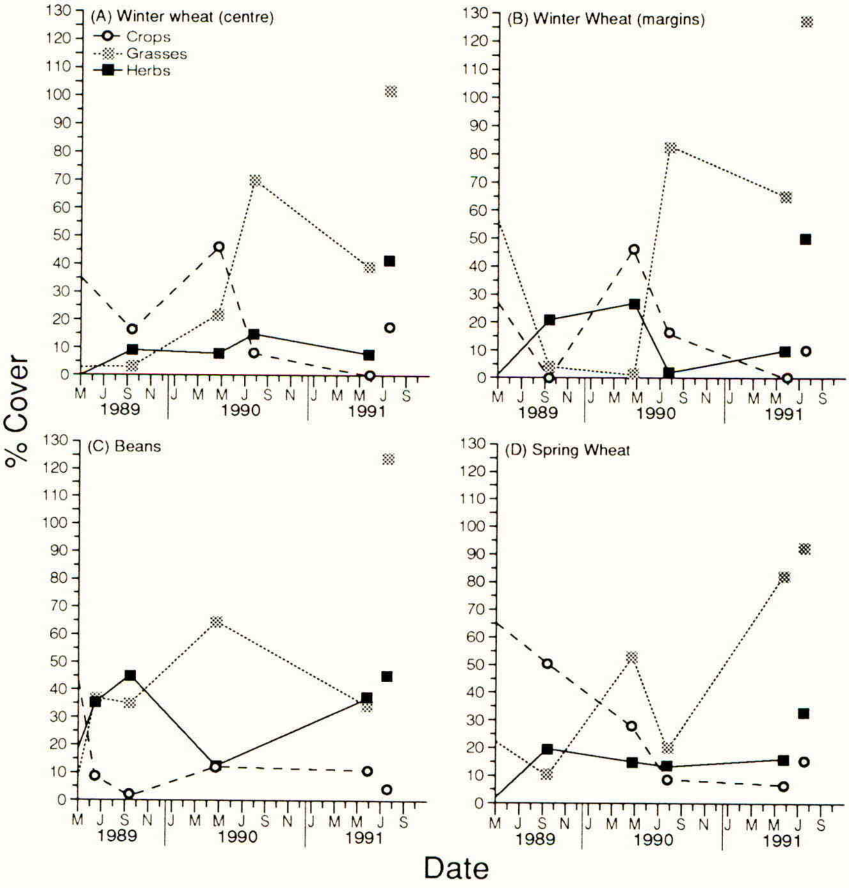

Fig. 1 Crop decline and plant colonisation showing mean % cover of all crop species (o crops), all non-crop grass species (▩ grasses) and all other plants (■ herbs) for each field crop preceding set-aside. July 1991 data are from a field survey: all other points are from photographs.

DISCUSSION

On this soil type, set-aside management has created a vegetation dominated by the grasses characteristic of the weed flora of arable fields and disturbed ground (Fig.1). The dominant species are short lived and have significant recruitment from seed. *A. myosuroides, B. sterilis* and *B. hordeaceus* are annuals and, in the fields studied, formed dense stands of single-tillered plants recruited each year from a large seed population on or just below the soil surface. *E. repens* was less abundant than the short-lived species and had increased more slowly. It formed discrete patches probably created by vegetative spread. Although forbs were less abundant and increased more slowly than grasses, tall emergent species were a very obvious feature of the set-aside vegetation. The spring wheat and, to a lesser extent, the bean field were characterised by tall spikes of *R. crispus* and the winter wheat field by yellow flowers of *P. echioides* over an annual grass carpet.

Although the number of species increased, the diversity index did not. The increased number of species was balanced by greater inequality in relative abundance; a few species became extremely abundant. This pattern was consistent with increasing interspecific competition. The closed grass sward will have made it unlikely that the arable weed species in the seed bank will succeed in the above ground vegetation. The dominant species were present and abundant in the flora of the set-aside fields from the first year. This suggests that an increase in some of the undesirable weed species in set-aside fields may be controlled by the early establishment of appropriate cover species. Weed control by sown covers has been demonstrated by Fisher and Davies (1991). Little difference was detected between the marginal quadrats and those in the centre. The edge effect in the fields studied was restricted to a few metres into the fields and the set-aside vegetation was probably recruited from species present in the fields with the last crop either as weeds or dormant seeds.

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THE INFLUENCE OF FIELD BOUNDARIES ON RECOLONISATION OF SET-ASIDE

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ABSTRACT

The influence of a field boundary and an old hedge line on an adjacent field of set-aside land was assessed by comparison with an isolated central portion of a large field on the same farm. The presence of the boundary increased the number of species in the adjacent field by acting as a source of colonising species.

INTRODUCTION

Land that has been set aside will develop a new plant community that stems from two sources. First, species will be recruited from the bank of seeds and other propagules within the field and second, species will be recruited from the seed rain. Marshall and Hopkins (1990) have shown that some species will disperse into a crop from field boundaries and have noted certain distribution patterns. However, only a small proportion of field boundary flora appears to be capable of spreading into fields under cultivation. The situation once the field is set-aside will be different and is investigated here.

METHOD

The study site was situated in North Bedfordshire on chalky boulder clay. It has been permanently set-aside since the autumn of 1987 under a Countryside Commission Premium Scheme allowing natural regrowth of vegetation with no cutting. To investigate the influence of the field boundary on the recolonisation of the site-aside, the vegetation at two sites was compared. Site 1 was an area 100m x 40m adjacent to a field boundary and fragments of hedgerow. The recolonisation of this site would be influenced by the field boundary. Site 2, free of any influence of the boundary, was an area 100m x 60m at the centre of a large field and at least 300m from the boundary. Thus this site is unlikely to be influenced by recolonisation from the field boundary.

Species occurrence, each site was determined by walking through the area and carefully searching for the species present. This was done 7 times between March and September 1991.

Species abundance was determined for 100 x 1m plots in each site. In the case of site 1, the natural boundary was the hedge line and the plots were spaced at varying distances from this site boundary, For Site 2, there is no natural boundary and the plots were evenly spaced throughout the plot. The vegetation in each plot was sampled using 10 randomly placed $0.25m^2$ quadrats. In each quadrat, the percentage cover of each species was recorded.

RESULTS

A greater number of species were found in the headland, Site 1, compared with the midfield, Site 2, (see Tables 1 & 2). Species at Site 1 were a mixture of those found in the isolated field and the hedge (see Table 1). The ratio of perennials to annuals was greater at Site 1 than Site 2 (see table 2) and 65% the perennials at Site 1 were also found in the boundary. Wind dispersed species were more common in Site 2 (see Table 2) and all the perennials in Site 2 were wind dispersed.

Table 2. The characteristics of all species found at each site.

	Hedge	Site 1	Site 2
Total no. species	33	34	18
% Perennials	80	55	38
%Biennials	6	9	25
% Annuals	15	36	38
% Wind dispersed	9	20	50

A similar difference in the number of species at each site was found in the quadrat samples with Site 1 having the more diverse community (see Table 3). Within Site 1, species diversity was greatest (although not significantly so) at 5-10m from the boundary. Here both colonising interstitial species and true field species were found.

Table 3. The mean number of species found in the plots of the two sites.

	Site 1	Site 2
Number	7	6
Mean	14.86	11.17
Standard deviation	2.12	1.33
Independent sample 't'-test		3.819
Significance		<0.01

Several species had distribution patterns that conformed to those that Marshall (1989) found in cultivated fields:

a. Boundary species limited to the field margin and rarely found in the body of the field eg *Stachys silvatica* and *Filipendula ulmaria*.
b. Species limited to the field but occasionally found in the hedge bottom eg *Veronica hederifolia* and *Leontodon hispidus*.
c. Species with maximum abundance at the boundary and decreasing with distance into the crop eg *Heracleum sphondylium* and *Bromus sterilis* (see fig 1).
d. Species distributed through the headland with highest densities between 1-5 metres from the field edge eg *Poa annua* and *Bromus mollis* (see fig 1).

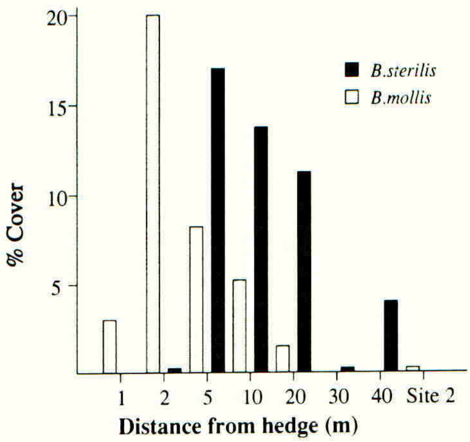
These patterns seem to persist after cultivation has ceased. However, a further pattern was recorded showing an absence of the species adjacent to the boundary and then distributed

Table 1. The occurrence and characteristics of the herbaceous species found at each site .

		Hedge	Site 1	Site 2
Annuals	*Alopecurus myosuroides*	*	*	*
	Avena fatua		*	*
	Bromus commutatus			*
	Bromus sterilis		*	*
	Galium aparine		*	*
	Geranium dissectum	*	*	*
	Myosotis arvensis		*	
	Poa annua	*	*	
	Sinapsis arvensis	*	*	*
	Sonchus asper		*	*
	Tripleurospermum maritimum		*	
	Triticum aestivum		*	
	Veronica hederifolia		*	
	Vicia tetrasperma	*		
Biennial	*Anthriscus sylvestris*	*		
	Cirsium vulgare		*	*
	Crepis vesicaria			*
	Dipsacus fullonum	*	*	
	Picris echioides			*
	Senecio jacobea		*	*
Perennial	*Agropyron repens*	*	*	*
	Arrhenatherum elatius	*	*	*
	Cirsium arvensis	*	*	*
	Convolvolus arvensis	*	*	*
	Dactylis glomerata	*	*	
	Epilobium lanceolatum	*	*	*
	Equisetum arvensis	*		
	Festuca pratensis		*	
	Filipendula ulmaria	*		
	Heracleum sphondylium	*	*	
	Holcus lanatus	*		
	Lolium perenne	*	*	
	Leontodon hispidus		*	
	Mercurialis perennis	*		
	Plantago major		*	
	Poa pratensis	*	*	
	Rumex hydrolapathum	*		
	Rumex sanguineus	*	*	
	Ranunculus repens		*	
	Rumex obtusifolius		*	
	Scrophularia nodosa	*		
	Sonchus arvensis		*	*
	Stachys sylvatica	*		
	Stellaria holostea	*		
	Taraxacum officinale		*	
	Tamus communis		*	
	Urtica dioica	*		
	Vicia cracca	*		

across the field eg *Alopecurus myosuroides*. This is probably due to past agricultural practice where the headland received extra cultivations and sprayings.

Fig 1. The % cover of *Bromus sterilis* & *B. mollis* at Site 1 with increasing distances from the hedge.



Arrhenatherum elatius var bulbosum had been present as an arable weed in Site 2 before set-aside. The presence of dense mats of decaying bulbils across the field indicated a very rapid spread after cultivation had ceased. The subsequent mortality was probably due to drought stress or overcrowding.

CONCLUSION

The boundary does exert an influence on the colonisation of plant species and subsequent diversity of the adjacent field. Site 1, in contrast to the isolated field, Site 2, had twice as many plant species. Many of these additional species in Site 1 were also found in the field boundary. Thus, the proximity of ancient habitats such as hedgerows to set-aside land appears to enhance its restoration and conservation value.

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EFFECT OF TIMING AND FREQUENCY OF CUTTING ON PERENNIAL BROAD-LEAVED WEEDS

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ABSTRACT

The initial year of a three year experiment is described. Cutting treatments at different timings, together with some spray and wick applicator treatments were applied. One "target" weed species was present at each of five sites. Percentage change of plant numbers in fixed quadrats are reported for June 1992 at a time when only the first year treatments had been applied. At one site Rumex obtusifolious showed an increase since 1991 but at another site it decreased. Cirsium vulgare was almost eliminated by almost all treatments at one site while Cirsium arvense was much reduced at another. Sonchus arvensis increased on the cut treatments but was reduced where sprays were used.

INTRODUCTION

The UK Weeds Act, 1959, requires farmers and landowners to prevent the spread of Cirsium, and Rumex species from their land. After the introduction in the UK of the set-aside scheme in 1988, it was found that these species became common on set-aside land but very little information was available on which to base advice for controlling them. They are well controlled by cultivation and normal herbicide use in arable farming and can be chemically controlled in grassland or waste ground but this is not normally possible on set-aside.

Cirsium arvense is spread by the wind and is therefore thought to be more of a problem than weeds which shed the majority of their seeds in situ. However, work in Germany (Eggers, 1978) indicated that only 3.7% of C. arvense from various sources germinated in the laboratory under optimum temperature conditions (25-30°C). Moreover, seed dispersal was severely limited because the pappus becomes separated from most of the seed and it was concluded that sexual reproduction played a minor role in the spread of this species.

Work in Australia (Amor and Harris, 1975) indicated that C. arvense was unlikely to spread rapidly by seed under permanent grassland. No seedlings were established from seed artificially spread on pastures but seedlings emerged from seed sown 0.5-1 cm deep into bare soil.

Cirsium vulgare however is entirely dependent on seed propagation and in set-aside fields it probably comes from the normal arable seedbank rather than having blown in since the set-aside began.

The treatments in the experiment covered by this paper were designed to compare various cutting timings for the control of the target species and other broad-leaved perennials present at the sites. In particular, they were designed to test late cutting treatments because it has been suggested from field observations that late cutting might be more effective than frequent cutting for reducing weeds. Late cutting also avoids the disruption of nesting birds.

MATERIALS AND METHODS

To provide a comparison with the cutting treatments, spray and integrated cut/spray treatments were introduced together with an optional Wick Applicator treatment.

TABLE 1. Treatments for year 1 and year 2.

	Timing - Year 1			Timing - Year 2		
Treatment	A	B	C	A	B	C
1	cut	-	-	cut	-	-
2	-	cut	-	-	cut	-
3	-	-	cut	-	-	cut
4	cut	-	cut	cut	-	cut
5	cut	-	cut	cut	-	-
6	cut	cut	-	cut	-	-
7	cut	cut	-	cut	cut	-
8	cut	cut	cut	cut	cut	cut
9	cut	-	spray	spray	-	-
10	cut	-	-	spray	-	-
11	spray	-	-	cut	-	-
12	cut	-	spray	cut	-	spray
13	spray	-	-	spray	-	-
14	spray	-	spray	spray	-	-
15	spray	-	spray	spray	-	spray
Optional - Wick Applicator (WA)						
16	WA	-	-	-	WA	-
17	-	WA	-	WA	-	-

Treatment timings: A Early flower bud stage of the target species
B Target species in full flower (treatment 2)
C Target species has viable seed but not yet ready to be detached by the wind (treatment 3)

Spray treatment: mecoprop-P (600 g/litre) at 2.5 l/ha product in 250 to 330 l/ha water.

Wick Applicator: glyphosate.

Five sites, on fields of set-aside were chosen in spring 1991. The only criteria for selection was that there should be a good distribution of at least one species of the target weeds. Plots were a minimum of 2m x 10m in three replicates. A randomised block design was used.

Cutting was done with flail, rotary or reciprocating knife mowers, and all cuttings were left *in situ*.

TABLE 2. Target weeds measured in June 1992 expressed as a percentage of the population at the start of the experiment in 1991.

YEAR 1 TREATMENTS Timings				Site 1 Cambridge *R. obtusifolious* %	Site 2 Cardiff *R. obtusifolious* %	Site 3 Starcross *C. vulgare* %	Site 4 Trawsgoed *C. arvense* %	Site 5 Leeds *S. arvensis* %
	A	B	C					
1	Cut	-	-	104.3	51.4	0.0	52.4	11.5
2	-	Cut	-	271.4	51.3	0.0	33.4	19.1
3	-	-	Cut	122.8	53.7	0.0	29.8	0.5
4	Cut	-	Cut	203.5	62.5	0.0	33.1	54.9
5	Cut	-	Cut	197.3	39.6	0.0	16.2	450.8
6	Cut	Cut	-	162.9	45.0	0.0	51.7	7.3
7	Cut	Cut	-	161.6	46.9	6.6	89.8	1717.5
8	Cut	Cut	Cut	242.8	48.0	0.0	65.5	378.5
9	Cut	-	Spray	102.5	24.0	0.0	40.4	100.0
10	Cut	-	-	154.0	43.4	0.0	20.0	178.0
11	Spray	-	-	88.7	31.8	5.7	36.7	4.1
12	Cut	-	Spray	113.9	57.5	0.0	50.0	0.3
13	Spray	-	-	70.6	29.4	5.7	37.9	1.2
14	Spray	-	Spray	100.0	50.3	0.0	49.7	100.0
15	Spray	-	Spray	98.1	46.7	0.0	34.0	1.4
16	WA	-	-	180.4	28.3	26.6	47.1	-
17	-	WA	-	108.3	34.6	0.0	67.1	-

KEY

A. Early Flower Bud Stage
B. Full Flower
C. Viable Seed Stage

WA. Wick Applicator

Assessments of plant populations were made prior to any treatments being carried out in 1991 and at the early bud stage (June) 1992. Further assessments will be made in 1993 at the same stage. All assessments were made in at least five fixed quadrats of $1m^2$ in each plot.

Further sites have been established during spring 1992.

RESULTS AND DISCUSSION

The two Rumex obtusifolius sites gave completely different results, with site 1 showing big increases across most of the treatments, while at site 2 the percentage of plants remaining ranged between 24% and 62% (table 2). The only reductions in target weed numbers at site 1, were on the spray treatments, and on site 2 the biggest reductions were on the spray and the wick applicator treatments.

The C. vulgare site has seen virtually all its target weed population disappear with no obvious treatment effects.

On site 4 C. arvense was consistently reduced over the range of treatments with no clear cut pattern emerging from the treatments.

All the spray treatments appeared to have controlled Sonchus arvensis effectively, but on the cutting only treatments there were some conflicting results with one double cut treatment resulting in an increased population level, while an identical treatment (identical in the first year only), showed a big reduction in numbers.

The experiment is designed to examine the effects of the treatments over a two year period. Therefore, only once the second year treatments and the second phase have been completed and the results fully analysed will the full effects of the treatments become more apparent. The results given should be regarded as an interim report on any final conclusions.

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Arrhenatherum elatius - A POTENTIAL PROBLEM UNDER SET ASIDE ?

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ABSTRACT

A study has been made of the distribution of the bulbous growth forms of *Arrhenatherum elatius* in the U.K.. The preliminary results indicate interesting differences in the distribution patterns of these bulbous growth forms growing in different habitats. Experimental work on the relative competitive ability and growth of a range of *A.elatius* populations indicates that one of the primary forces shaping their distribution in semi-natural habitats is the performance of individuals under differing moisture regimes. The distribution of the agricultural weed form of the species is not explained; experimentation has failed to indicate any preference for soil-type, often suggested as a major factor in determining the success of the weed at specific sites. The potential for *A.elatius* to become a problem on land abandoned from agriculture (*e.g.* set-aside) in both the short and long term certainly exists, but the significance of the threat will remain unquantified until further data are obtained.

INTRODUCTION

Arrhenatherum elatius is a perennial grass, almost ubiquitous within the U.K. (Pfitzenmeyer,1962). It is frequently observed both as an arable weed, and as a component of extensively managed semi-natural grasslands. The species is highly polymorphic, and exists as a number of sexually compatible growth forms (sometimes raised to the rank of subspecies or variety). The primary morphological characteristic which differentiates growth forms is a swelling of one or more basal internodes. In the growth form which occurs as a troublesome weed of arable land, this swelling is at its most extreme, with a chain of 4 to 7 swollen basal internodes of up to 9mm in diameter being present. In semi-natural habitats both bulbous and non-bulbous growth forms are found. The bulbous individuals in semi-natural habitats vary in their degree of bulbosity, but none are as extreme as the arable bulbous form.

This paper describes an attempt to define the distribution patterns of the bulbous forms of *A.elatius*, and more importantly to identify primary factors which shape these distributions.

METHODOLOGY

Distribution Survey

Records of the occurrence of the bulbous forms of *A.elatius* were collected from a variety of sources, most notably from members of the Botanical Society of the British Isles (Cussans and Morton, 1989). These Records were mapped to a 10km resolution using a computer program DMAP (Morton, 1992). To supplement records of the occurrence of the bulbous growth forms, the relative abundance of bulbous and non-bulbous individuals was assessed in four semi-natural grasslands where *A.elatius* was the dominant grass species. Two sites were in the west of the U.K. in Wales (near Machynlleyth) and in Cornwall (Liskeard), the other two sites were further east, one at Reading (Berkshire), and the other near Stoneleigh (east Midlands). Fifty 0.5x0.5m quadrats were randomly placed, and all the *A.elatius* individuals (Tussocks) which lay wholly or partly within the quadrat were recorded as bulbous if they possessed any tillers with internodes swollen to over 5mm in diameter, otherwise as non-bulbous.

Competition under differing moisture regimes

Plants from three different populations of *A.elatius* were collected;

i) Non-bulbous individuals from abandoned allotment plots in Reading (Berkshire).

ii) Bulbous individuals from a roadside rough grassland near Liskeard (Cornwall).

iii) Bulbous individuals growing as a weed in a field near Stoneleigh (east Midlands).

The experiment was laid out as two DeWit replacement series (DeWit, 1960) consisting of seven mixture treatments, with a total density of six plants per 2 litre pot. Both bulbous populations (ii and iii) were grown in competition with the same non-bulbous population (i);

Replacement Series A - Population i(Reading) VS Population ii(Liskeard)

Replacement Series B - Population i(Reading) VS Population iii(Loxley)

Three different moisture treatments were also applied. Two replicates of all possible population type/mixture/moisture treatment combinations were planted.

Growth in differing moisture regimes and soil types

Individual ramets from three populations of *A.elatius* were planted into pots of three soil types; a very calcareous loam, a light free-draining sandy soil and a heavy clay. The pots were subjected to two watering treatments. Three replicates of all possible treatment combinations were planted. The plants used in this study were;

i) Non-bulbous individuals from abandoned allotment plots in Reading

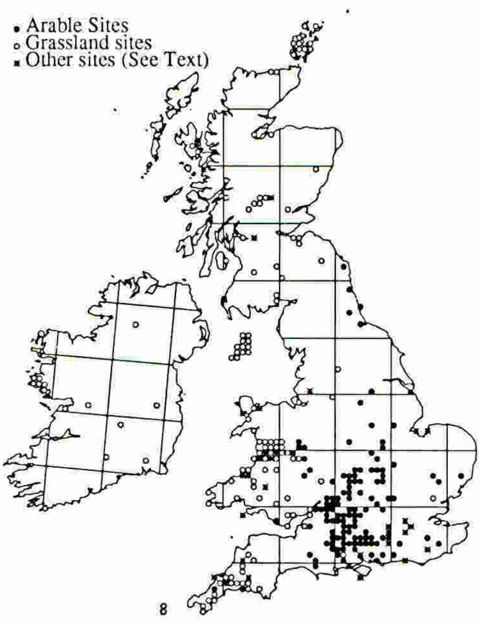
ii) Bulbous individuals from a roadside rough grassland near Machynlleyth (Mid-Wales).

iii) Bulbous individuals growing as weeds in a field near Chipping Sodbury (Wiltshire).

RESULTS

Distribution Survey

FIGURE 1 - Preliminary results of a distribution survey of *A.elatius* ssp. *bulbosum*



It can be seen from Figure 1 that bulbous individuals growing in different habitats show contrasting distribution patterns. In semi-natural grassland habitats the pattern is of increased occurrence in the extreme west of the U.K., and an almost total absence from the east. In arable habitats where the plant is considered a pernicious weed, the pattern is of a strip of sites running south-west to north-east across the centre of England.

The increased abundance of bulbous individuals in semi-natural habitats in the west, which Figure 1 implies, was confirmed by assessment of individual sites. At both eastern sites the quadrats assessed only contained non-bulbous individuals. A subsequent thorough search of both sites failed to reveal any bulbous individuals. At the two western sites assessed, the bulbous form was the dominant one, with 67% and 80% of the clonal individuals being recorded as bulbous in the Cornish and Welsh sites respectively.

Competition under differing moisture conditions

Table 1 illustrates the results from the two parallel DeWit replacement series, which were carried out under differing moisture treatments. These results indicate that the bulbous individuals originally from a western semi-natural grassland habitat became increasingly competitive (indicated by their increasing Relative Crowding Coefficient,RCC; Table 1) relative to the non-bulbous (eastern) individuals with **increasing** moisture supply treatment. Conversely the bulbous individuals originally collected from an arable habitat became increasingly competitive relative to the non-bulbous form with **decreasing** moisture supply.

TABLE 1 - Results of the experiment on the competitive ability of populations of *A.elatius* grown under differing moisture regimes.

Populations Grown in Competition.		Moisture Supply Treatment High	Medium	Low
Non-Bulbous(i) VS Arable Bulbous(ii)	**RCC**	**0.706**	**0.777**	**1.043**
	(RSS)	(7.93)	(7.51)	(9.49)
Non-Bulbous(i) VS Semi-natural Bulbous(iii)	**RCC**	**1.066**	**0.917**	**0.854**
	(RSS)	(18.98)	(12.83)	(5.01)

Growth in differing moisture regimes and soil types

No consistent or significant differences were recorded between the various soil types. Moisture treatment had a significant effect ($P<0.01$) on plant growth. The percentage reduction observed under the lower moisture treatment being higher for semi-natural bulbous plants than for non-bulbous plants ($P<0.05$), but lower for arable bulbous plants than non-bulbous plants ($P<0.1$). These data are shown in Table 2. The results obtained by analysis of the monoculture data only from the first experiment are in agreement with these data, indicating that the response to moisture supply treatment of bulbous plants from different sites of the same habitat type is consistent.

TABLE 2 - The effect of low moisture regime on the growth of *A.elatius* plants, expressed as a percentage of their growth at the highest moisture treatment.

Type of *A.elatius* population	Total Plant Weight Mean	(S.E.)
Bulbous (Arable)	**21.95**	(1.09)
Bulbous (Semi-natural)	**34.40**	(0.73)
Non-bulbous (Semi-natural)	**24.60**	(0.79)

DISCUSSION AND CONCLUSIONS

The preliminary survey presented in this paper highlights the contrasting distribution of bulbous growth forms of *A.elatius* growing in different habitats (Figure 1). Experimental results (Tables 1 and 2) go some way to explaining the predominantly westerly distribution of bulbous plants growing in semi-natural habitats, indicating that differences in moisture regime, probably induced by rainfall patterns east to west, may play a key role. Experimental data have, however, failed to explain the nature of the distribution of the weed form ('Onion Couch'). A requirement for specific soil-type which is often suggested (*e.g.* Khan,1985) is not confirmed by these data.

Although these results (Table 1) indicate that the weed form is at a competitive disadvantage, other current work (Miller *et al*, 1992), together with personal observation and discussion with fellow workers, suggest that a significant proportion of the original weed population would remain in infrequently defoliated grassland for long periods, certainly for as long as the current 5yr set-aside cycle. Indeed in the initial period after cessation of cultivation we would expect a population expansion.

Where fields with an existing weed problem are turned over to set-aside, there is certainly a potential for the problem to be carried over into subsequent crops. More usually the *A.elatius* in set-aside areas will arise through invasion by semi-natural populations. Non-weed forms of *A.elatius* can be a significant component of the grassland which results from abandonment of arable land (Wells *et al*,1976). The results presented here indicate that the bulbosity of the population which arises on such land will differ greatly from east to west, and most probably with soil moisture conditions. These semi-natural forms are not, necessarily, in themselves potential weeds, they are particularly susceptible to cultivation and herbicide treatments. However if the bulbous semi-natural form possesses the capacity to give rise to extremely bulbous weed individuals, they may represent a threat to the future of specific set-aside areas. The probability or even possibility of this process is unclear. Arable weed populations do not appear to breed true, suggesting a high degree of recessiveness (Khan,1985). Also a simplistic genetic model of a continuum of compatible forms, running from non-bulbous to semi-natural bulbous to the extreme weed form, is called into question by the contrasting responses to moisture (Tables 1 and 2) and other characters observed in bulbous individuals from differing habitats. Further data are required on the nature of the relationship between the growth forms to assess the significance of the threat of *A.elatius* in set-aside to subsequent arable crops.

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