SESSION 4B

CHANGING VEGETATION AND WEED FLORAS WITH NEW LAND USE PRACTICES

CHAIRMAN	DR M. J. HUTCHINGS	
SESSION ORGANISER	DR E. J. P. MARSHALL	
INVITED PAPERS		4B-1, 4B-2
RESEARCH REPORTS		4B-3 to 4B-6
POSTER		4B-7

PERSPECTIVES FOR NATURE IN DUTCH AGRICULTURAL LANDSCAPES

W. JOENJE

Department of Vegetation Science, Plantecology and Weed Science, Agricultural University, Bornsesteeg 69, 6708 PD Wageningen, The Netherlands.

ABSTRACT

Nature in the Dutch agricultural environment has been deteriorating. Nutrient loading, acidification, and pesticide losses affect conditions of soil, surface- and groundwater. These stress factors and their effect on natural communities and species are quantified on a national basis. The new policy (National Environmental Policy Plan; Nature Policy Plan) is discussed with respect to the chances of repair and conservation of nature in and outside the Environmentally Sensitive Areas and with changing farming practices.

INTRODUCTION

In the Netherlands essentially a flat sedimentation area (65% in agriculture) void of rocks or height differences, the countryside has been intensively managed to sustain a highly developed agricultural production. It has been an outstanding success with still rising production levels. Not only coastal polders, but also poor sandy soils, heathlands and peat have been put into agricultural production. However, the success story is quickly losing its glamour. Serious problems can no longer be denied and indeed have found their political translations. "There is something rotten in the borough". Many species of breeding birds, butterflies, flowering plants are vanishing, trees suffer and fish can no longer be eaten safely (Weinreich & Musters, 1989).

The environmental problems generated in our urbanized areas relate only to part of the problems for nature in the countryside. There is a background load of acid rain (5300 mol $H^+.ha^{-1}$ yr^{-1} in 1989) and toxic substances, nutrients and heavy metals distributed by the surface waters (the river Rhine providing the water for the major part of the country (Hekstra & Joenje, 1986)). However, while seriously impoverishing nature areas, soft-water systems and woodland, this burden does not much influence the arable field. Agriculture itself produces an output of nutrients and pesticides, which deteriorate environmental quality and nature values nation-wide. This environmental impact has become an important aspect in current changes in land use planning, as well as in the search for adaptations towards sustainable cropping systems.

The purpose of restoring and improving nature-qualities in the agricultural countryside has led to many experiments, activities and incentives, both private and governmental, some of which will be elucidated. Nature reserves are only mentioned with respect to their place in land use policy, where their vulnerable status has become gradually acknowledged.

Figure 1. The ecological Main structure for the Netherlands

THE ENVIRONMENTAL IMPACT OF AGRICULTURE

Nature uninfluenced by man has not existed in the Netherlands for a long time. The land has been moulded and reshaped but former land use patterns still provide a wealth of semi-natural communities such as species-rich grasslands, heathland, peat and swamps and small scale, diverse rural landscapes. The agricultural intensification, the lowering and regulation of the watertables and reallotments increasingly segregates nature from culture areas, notwithstanding the ever louder call for nature and landscape conservation. Surveys of the desintegration of ancient agricultural landscapes of all EC countries have been recently reviewed (Anon.,1990b).

In 1975 the government published the so-called Relation Act (Relatienota) describing the interaction between agriculture and nature and landscape conservation. Consequently certain areas (100 000 ha; another 100 000 ha now being identified) were identified as environmentally-sensitive areas (ESAs), where farmers can conclude management agreements (EC-agreements 75/288, the mountain farmers compensation, and 799/85, the management compensation). The Relation Act comprises areas with existing nature reserves and other valuable areas which will be bought (on a voluntary basis) and similarly managed.

Recently, the alarming diagnosis has led to new policy with respect to land use in general, agricultural practices and nature and landscape conservation (National Environmental Policy Plan (NMP) (Anon.,1989b) and Nature Policy Plan (NBP) (Anon. 1990a)). In the NBP the environmentally sensitive areas have become part of the so-called Ecological Main Structure with core areas and nature development areas. In the perspective of the NBP this ecological network (Fig.1) will provide a sustainable base for the nationally and internationally important ecosystems and species.

A substantial part of the country is under the special status mentioned, where agriculture is restricted or will stop in the (near) future and change to a nature-directed management. The larger part of the map shows a countryside apparently free for all agriculture. However, in the NMP this agricultural environment must be improved in order to meet the new standards of a defined Basic Environmental Quality. In the following we will determine the possibilities for nature in tomorrow's production landscape.

Present environment

Even in the modern agricultural landscape there are numerous, semi natural elements such as verges along roads and trails, watercourses, dikes and railways. Small woodlots, fens and swamps, but also hedgerows and fences, drinking pools, farmyards still harbour a variety of spontaneously occurring organisms. These communities in the perimeter of arable fields, impoverished as they are, display clear responses to modern agriculture and many species are almost lost: ox-eye daisy, poppy, cornflower, partridge, yellow and corn-bunting, many species of butterflies and dragonflies, barn-owl, badger, otter, to mention just a few. The impoverishments were articulated by ecologists and others, but did not develop into a social argument. The alarm was raised only after the discoveries of pesticides in precipitation, ground- and drinking water and other hard evidence of environmental pollution. Such problems are reported from many areas with longer histories of high usage (cf. Hallberg, 1986 for USA). It seems however that the Dutch condition holds a warning for our neighbours.

Losses of Nitrogen and Phosphorus

The recent studies on the environmental impact of agriculture has brought new policy, formulated in the Statement on Agricultural Structure (Anon. 1989a), related to NMP and NBP. This leads to a thorough review of agriculture and other land use practices. The prolific use of chemical nutrients and manure is shown in Table 1 and demonstrates the unbalance between input and output of Nitrogen. In the year 1985/86, the Phosphorus input exceeded the withdrawal by 159 x 10^6 kg (Anon., 1989b).

TABLE 1. Nitrogen balance of Dutch agriculture, cattle (grass and maize included) and field crops in 1985/86 (kg N x 10^6 yr^{-1}).

	fertilizer N	concentrates	output	difference
NL total	495	418	265	648
cattle	355	129	77 (382)	407
field crops	105	-	78	27

(from Van der Meer *et al.*, 1989)

The average ha in the Netherlands may well loose 300 kg N per year to the environment, apart from over 50 kg N ha^{-1} $year^{-1}$ added by precipitation. Regulations are now developing towards a minerals-accountancy per farm for N, P, K etc. and for manure. However, the country continues to receive large surpluses of nutrients from abroad (concentrates) and several notoriously stinking regions illustrate this dung-hill syndrome.

Quotas do not yet tackle the problem. However, the number of animals will be linked again to the land area (3 cattle per ha). The timing and the quantities of manure application and the levels of phosphate (in any form) and nitrate will be prescribed.
The emission of NH_3 from animal production is damaging the environment. Amounts of 10 000 H^+ equiv.ha^{-1} y^{-1} are found locally along forest edges. Together with SO_2 from outside agriculture, the acidification-process is changing soil conditions. This especially threatens sandy areas where the pH is lowered and toxic Al^{+++} is mobilized (Van der Aart *et al.*1988). Many plant species are affected, particularly those with mycorrhizal symbiosis (spp. of trees, orchids). The NH_3 emission level of 1980 has to be lowered with 70% by various mitigating measures.

Additions of N and P, notably the mobile N fertilizers increase the production of biomass, also in the boundary of a field. This not only means extra work, but also stimulates competitive perennial plants at the cost of overall biological diversity. This phenomenon is often described and discussed (*e.g.* Grime 1979). The reverse equally applies and the removal of biomass and litter, as in a mowing regime, exhausts the nutrient pool in the soil and increases species diversity (Fig.2). In the modern production landscapes the predominance of coarse weedy species of grasses and forbs illustrates the over-all ruderalization process.

The widespread growing of maize for silage has increased the excess manuring, this crop being very tolerant to high doses, as well as the output to the boundaries and the groundwater. In several regions the concentrations of N in the groundwater is many times the safety level and soils have become saturated with and start leaking phosphate. As a consequence, the laterally moving groundwater transports unknown quantities of nutrients (and other compounds) which are, or may become, a problem in the region, especially in nature reserves and drinking-water areas. Most surface-waters and ditches transport highly eutrophic drainage water and harbour very productive aquatic communities, which have to be managed at high cost.

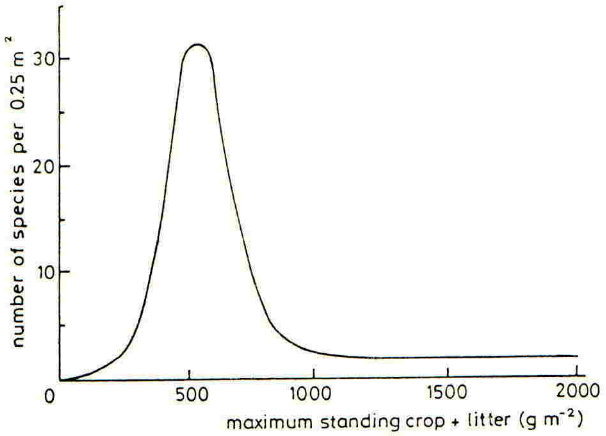

Figure 2. The relation between number of species and biomass (including litter).

According to the recent policy the application of P and other minerals will be lowered to the level of extraction by the crop; these levels are to be formulated later (e.g. silage maize in 1991 200 kg, in 1995 175 kg, in 2000 ....kg P_2O_5).
Rules for the application of N fertilizers -artificial, animal and other origin- are being developed in order to guarantee a level of no more than 50 mg nitrate in the groundwater at a depth of 2 m. In surface waters levels of N < 2.2 mg l^{-1} and of P < 0.15 mg l^{-1} are indicated, which would prevent the algal blooms and restore aquatic communities. These levels refer to the so called Basic Environmental Quality, which also describes the reference values for many other substances. In addition more severe environmental quality levels will be defined and applied to areas with other functions, such as drinking water production or nature conservation.

Pesticides

An important evaluation of the annual input of chemical compounds in crop protection was made in 1990 (The Pluri-annual Plan for Crop Protection [MJP-Gewasbescherming] and related studies, *e.g.* on the reduction of emission). Again Dutch levels appear to be the highest in Europe (Table 2).

The field crops account for 70% of the use (40% of the agricultural area). Of this amount the herbicides comprise 17%, the insecticides and fungicides 20 and the fumigants over 60%. The policy aims at a reduction of 50% by the year 2000 and a removal of environmentally harmful compounds by 1994. By then the reduction in soil fumigants (accounting for 50% of the total amount of a.i.) will be 80-90%. Furthermore the concentration of any particular compound in the groundwater will be kept below the level of 0.1 μg l^{-1} and the total amount will not exceed 0.5 μg.

TABLE 2. Sale of pesticides per year in kg a.i. per ha in agri-and horticulture in NW-European countries (pasture and amenity areas excluded). SF- soil fumigants; H- herbicides; I- insecticides; F- fungicides.

	SF	H	I	F	other	Total
The Netherlands	9.6	4.5	0.6	4.7	1.4	20
Belgium	1.3	6.8	0.6	3.0	0.5	12
Germany	<0.1	2.3	0.2	1.2	<0.1	4
France	0.2	2.2	0.4	2.9	0.3	6
Switzerland	-	-	-	-	-	6

(after MJP-Gewasbescherming, Anon. 1990d).

It appears that spraying transports substantial amounts of pesticides over short distances outside the field of application; research and application rules focus on potential damage to adjacent crops. However, there is virtually no research on other likely effects of e.g. herbicides on bordering vegetation of arable fields. Permanent plots need to be monitored for several years. Most often plants are exposed to sublethal doses (compare Table 3) and die because of a lowered vitality: the general impression from hedgerows and boundaries is that grasses and resistent forbs gradually have replaced many dicotyledonous species.

The same will hold for insects and related animal life. Ecological food webs have become depauperate as is found in aquatic communities (MJP-G, Anon. 1990d). The potentials for biological control of plagues in the crop are diminished (Chaboussou, 1986). It remains difficult however to separate the effect of pesticides from other environmental stress factors.

TABLE 3. Losses of pesticides to the environment (total amount 6000 ton a.i. used on 2000.000 ha)

compartment	air	soil	water
% of annual sale (6000 ton)	21	2	2
drift (% of the applied amount)	1-17		
evaporation („ „)	10-20	(fumigants > 50)	

(from MJP-Gewasbescherming, Anon. 1990d)

In addition to the general data of Table 3 it must be stated that in specific cases much higher levels are to be found (wrong application techniques, wind) and damaging levels have been found in all three compartments. In field crops 0.1% of the amount applied was transported over 14 - 18m, while in orchards at a distance of 14m this was as high as 9%. In estimating the ecological significance of pesticide stress on the environment the peak values and also the timing and repeat of an application should be taken into account.

In view of these authorized data and of the policy of reduction, in relation with the sanitation of nutrient input, the ecological conditions in the agricultural countryside should gradually improve and a marked response of the bordering plant and animal communities can be expected.

RECONSTRUCTION AND REPAIR

Having depicted the current agricultural stress-factors and the national efforts to restore a basic quality and to secure the environmentally sensitive areas, we now come to more specific operations in favour of nature and environment.

Considering the farming practice, we see on the one hand a great many plans, experiments and practices aiming at improvements of crops, farming systems and related techniques, fed by new R&D. Here motives are not only the reduction of environmental pollution and restoration of the basic environmental quality, but also the economic EC pressure to lower and diversify production. Both motives could favour nature values.

Regarding nature on the other hand, the Nature Policy Plan has put forward new action plans for nature conservation. These include protection plans for priority (key-)species and groups and various forms of rewarding nature production.

The farming system

Particularly relevant to the ecological condition of the farmland are

- the execution of the new policy and legislation with respect to the use of pesticides and fertilizers, Nitrogen and Phosphorus. The task to reduce pesticide use 50% and to balance the nutrient input with the output by the crop, creates an enormous pressure on farming practice.

  Experimental farms have demonstrated the viability of an integrated approach: a minimal use of pesticides based on damage thresholds, a widening of the crop rotation, with (resistant) potatoes once, followed by three other crops, mechanical weed control and organic manure, with restricted use of chemical fertilizers. The system needs a high level of knowledge, field observations and risk assesment, as well as a certain change in mentality. Integrated farming is being tried out in several experimental farms and on many private farms. The introduction is financially facilitated and guided by the agricultural information service, since it represents the future farming practice.
- One single aspect might become a significant contribution: the rule to leave a margin unsprayed of 0.5 meter from the edge or slope of the ditch (MJP-Gewasbescherming, Anon. 1990d).
- In the ecological farming practice (including the biologic-dynamical (organic) and alternative agriculture) the sustainability approach has already created an environmentally more adequate system. Production levels being lower, the economic viability depends on the market for their EKO-products, especially vegetables. Increasingly, consumers are prepared to pay extra and the area under eco-farming is expanding and export and retailing structures are developing.
- Set-aside in the Netherlands comprises fallow (obligation to grow green manure, free rotation), afforestation (fast growing species) and the non-agricultural use of the land. The program comprises over 10 000 ha (2%) of arable land (over 90% fallow, 7% planted with trees, mostly in

the two northern provinces) and participation accellerates (613 farmers by Sep. 1990). The compensation amounts to Dfl.1853 per ha. The farmer has to enter the program for 5 years with at least 20% of his area. The program is not suited to field margin- or other nature management, since it needs at least one ha per parcel (Van Zwieten, 1990).

- The Land Use Planning (law of 1985) has become an important instrument in implementing new policies on nature and landscape conservation. In a land reconstruction project (landinrichtingsproject), the various uses (functions) of the project-area are integrated. Inventories of present natural, archaeological, historical values are prepared, but also a screening of the area takes place for possibilities of habitat (re)-creation and repair. This is perhaps the most important structure under which the abiotic conditions are defined for semi-natural communities.

  Recently the government has expressed the intention to bring the land reconstruction projects under the law on Environmental Impact Statement. This could have the effect of widening the analytical knowledge of the impact of farming practices and planned modifications on the landscape, in a public evaluation, with renewed discussions *e.g.* on the agricultural standards for hydrology and drainage, the use of groundwater for sprinkler irrigation etc. and enforcement of the environmental policy as in the NMP and NBP.

Improving nature qualities

Efforts explicitely aimed at developing nature in farmland are manyfold, both governmental and by private organizations. The former are expressed in the above mentioned procedure of Land Use Planning which focuses on the nature management areas under the ESA's. The efforts undertaken outside this area will be discussed further on.

The Relation Act-scheme enables the farmers in that area to conclude contracts and receive compensation based on a specified management plan. This can be related to, *e.g.* meadow birds (date of turning out stock, ban on mowing, rolling until the 1st, 8th, 15th or 22nd of June), flora and vegetation (timing and amounts of fertilizer dressings, use of agrochemicals). The farmer can select from 9 Types of Management (Table 4) and specify management packages (46 packages, with light to severe restrictions). The compensation is related to reference farms outside the management area. The draft management plan is open to public inspection and fixed by the Central Committee for Land Management.

In 1990, management plans were fixed for almost 60 000ha. The area where management contracts were actually concluded was 16 500 ha (+25% since 1989). This latter category is planned to grow to 33 000 ha by 1994. The acceptance of the sceme (based on voluntary participation) increased recently, partly through a more intensive acquisition, the number of participants now being 2653, a rise of 24% in the last year. The approach appears to be effective both for botanical and meadowbird communities (Melman & Boeschoten, 1991), the differences with the surrounding farmland often demonstrating a process of segregation.

Field margins

It appears that a management agreement on arable field margins is, as yet, only possible together with limitations for the whole field (in nr.6, Table 4). This is in contrast to the successful implementation of a 'Randstreifen-programm' in several German federal states where *e.g.* in Nordrhein-Westfalia in 1990 almost 1000 farmers joined, with 2240 kms of

TABLE 4. Types of Management Plans, their purpose and the areas or specifications involved, to be subsidized under the Relation Act.

Type of Management	Purpose	Area / specification
1. passive m.	- leaving natural handicaps (hydrology, hedges)	- peaty grassland, watermeadows, inundation areas, small-scaled countryside, hydrol-buffer area
2. buffer m.	- protecting neighbouring nature (reserves) from negative agricultural influences	- no manuring in autumn/winter, no pesticides
3. botanical m.	- preservation and development of species-rich grasslands, fields and boundaries	- limited use of manure, no pesticides, mowing/grazing in (late) summer
4. meadow-bird m.	- preservation and development of meadow-breeding-bird communities	- limited use of manure, no pesticides, no rolling, mowing etc. in breeding period
5. boundary	- preservation of grassland species and communities	- ditches, verges in grasslands
6. arable land	- extensifying production and restoring diverse arable communities/boundaries (weeds)	- no liquid manure/maize/pesticide
7. migratory birds	- grasslands to offer feed and rest to migratory birds, notably geese and waterfowl	- no agricultural activities from November till March
8. combination 2+4	- see above	
9. combination 3+4	- *id.*	
(10) maintenance of small elements	- preservation of trees, hedgerows, drinking pools etc.	- various reglementations

field margins. The results have stimulated Dutch research activities (De Snoo, 1991; Smeding *et al.*, 1990) and the arable field margin already is a recurrent issue in the NBP-projects on "conservation of arable herbs" (weeds), the "Partridge project" (Anon., 1991) and in the NBP-theme "nature-friendly farming". Field tests are being made by the province of Gelderland and in Groningen. A management package specified for arable field margins in the sand and clay regions, be it only in the ESA's, would greatly benefit several conservation purposes (threatened weed species and communities, insects/butterflies and bird species from the priority-list, including partridge and corn-crake.

<u>In and outside the ESA's</u>

Here we enter into a category of nature-directed, nation-wide actions under the NBP. They consist of 23 regional projects, 14 thematical projects and a series of species-projects. One theme is of relevance here: the project "nature-friendly farming". Experimental farms are and will be set up, both dairy farms (Van Paassen, 1991) and arable farms, in order to systematically explore the possibilities of stimulating the nature-appreciating ways of farming in different regions, fully applying the new policies in NMP and NBP.

<u>Priority species</u>

Under the NBP a number of projects on the protection of threatened species is being developed (quality-indicating or critical species, or those suited to strengthen the social acceptance of the nature policy). Plans for protection comprise farmland species like Barn Owl, Spoonbill, Partridge, Crane, various amphibians, threatened weeds and orchids. There will also be funds to stimulate management activities favouring bats, badger, geese, corn drake, pike, salmon, butterflies, dragonflies, ring snake, fritillary and others. Research programmes will be carried out on the ecology of still further species.

<u>Payment for nature production</u>

This brings us to a recent vivid discussion on the idea of paying a premium for the 'production' of certain species. It is interesting to note that in 1975 the Netherlands invented payment to farmers who accepted limitations in their farming practice. Now the production of individuals of plant or animal species might be rewarded. It has come that far. For example, the Barn Owl successfully breeding on a farm brought the owner Dfl.100. Following the population increase, as well as the acceptance and tolerance for this species, this reward has now been cancelled. This is how the system should work. A provincial experiment now comprises a payment for each successfully hatched meadowbirds nest.

The Nature production approach could very effectively make use of the local knowledge, experience and creativity of the farmer. Difficulties are in the assessment and policing of such schemes
A premium could be on species or communities which are easily recognized as well as controllable at reasonable cost. In principle, one can think of animal and plant species and associations, but also of ecological processes leading to a desired (more complete) biotope. However, inventive farmers can create pools or other new abiotic conditions (nature building) in order to grow the premium species. These schemes have to leave the original ecological relations intact. The species should be, or have been, a part of original habitats. Arable weeds would be relatively easy to encourage and to control. A thorough discussion and detailed proposals are given by Van Paassen *et al.* (1991).

Other Developments

The hydrology of the countryside, so important for agriculture is even more critical for nature conservation. The policy with respect to the surface waters is carried out by the Rijkswaterstaat in the Ministery of Traffic and Public Works, and by many regional Waterboards with respect to both the management of quantity and the quality of the waters, the dikes, banks and the riparian habitats. This multifunctional area is affected by the new environmental policies of the NMP and NBP, as it is related to the land use (planning) in many ways.

The Rijkswaterstaat has initiated a large project on the management of banks and shores for the benefit of nature (CUR, 1990)). The regional Waterboards perhaps work in the closest relation to agriculture. Here, many adjustments in the intensive maintenance of the 40 000 kms of ditches could lead to a relaxation of the ecological stress on the aquatic and riparian communities (Bommezij & Jaarsma, 1990).

While not discussed here, the private nature management authorities in the Netherlands have a strong historical basis. They add social pressure to hasten the implementation and popularisation of the new approaches and carry out many experiments, while managing their own nature reserves.

CONCLUDING REMARKS

Nature in the Dutch farmland environment could face a substantial improvement, **provided** that the policy to restore a basic environmental quality of soil, water and air, will be successful. That is, if we learn to farm on a sustainable basis. In my opinion this will be at least somewhere between integrated and ecological farming.

The new national Nature-related policy has drawn a consistent Ecological Main Frame, which, however, leaves large white areas. There is some fear that without the influence and financial means of the central government, the remaining nature and landscape elements will be eaten up by autonomous developments. This may not be realistic, however, since much remains dependent on the responsibility of each farmer, waterboard worker and the individual making use of the land. Promotion of sustainable farming, nature conservation and education are prime aspects, along with the cooperation between farmers and people with nature-oriented interests.

REFERENCES

Aart, P.J.M. van der; Aerts, R.; Bobbink, R,; van Dijk, H.F.G.; Koerselman, W. (1988) De invloed van vermesting op terrestrische ecosystemen. Landschap, 5, 253-269.

Anon. (1989a) Structuurnota Landbouw, beleidsvoornemen. Min. van Landbouw, Natuurbeheer & Visserij, Den Haag, 139 pp.

id. (1989b) (NMP) Nationaal Milieubeleids Plan: Kiezen of Verliezen. Min. van Landbouw, Natuurbeheer & Visserij, Den Haag, 258 pp.

id. (1990a) (NBP) Natuurbeleidsplan, regeringsbeslissing. Min. van Landbouw, Natuurbeheer & Visserij, Den Haag, 272 pp.

id. (1990b) Milieu: Environmental policy in the EC, growing problems, growing prospects. Special issue *Neth. J. Envir. Sc.* 5, 165-266.

id. (1990c) Rapport Werkgroep Beperking Emissie. Achtergronddocument MJP-G. Min. van Landbouw, Natuurbeheer & Visserij, Den Haag, 74 pp.

id. (1990d) Meerjarenplan Gewasbescherming (MJP-G). Min. van Landbouw, Natuurbeheer & Visserij, Den Haag, 133 pp.

id. (1991) Herstelplan leefgebieden Patrijs. Min. van Landbouw, Natuurbeheer & Visserij, Den Haag, 71 pp.

Bommezij, E.; Jaarsma, P. (1990) Waterschappen en Natuurontwikkeling. Publikatiefonds Milieukunde Nieuw Rollecate Nr.10, Deventer, 81 pp.

Chaboussou, F. (1986) How pesticides increase pests. *The Ecologist*, 16, 29-35.

Clausman, P.H.M.A.; Melman, Th.C.P. (1991) Instruments for combining intensive dairy farming and nature conservation in The Netherlands. *Landscape and Urban Planning*, 20, 205-210.

CUR, (1990) Milieuvriendelijke oevers: voorlopige leidraad voor een integrale benadering van ontwerp, aanleg en beheer van oevers. CUR rapport 90-4, Gouda, 428 pp.

Elliot, J.G.; Wilson, B.J. (1983) The influence of weather on the efficiency and safety of pesticide application: the drift of herbicides. BCPC publications, Surrey, 135 pp.

Grime, J.P. (1979) Plant strategies and vegetation processes. John Wiley & Sons, Chichester.

Hallberg, G.R.,(1986) From hoes to herbicides; agriculture and groundwater quality. *J. Soil & Water Conservation*, 41, 357-364.

Hekstra, G.; Joenje, W. (eds),(1984) Rijnwater in Nederland: Ecologische consequenties in het benedenstroomse gebied van de verontreinigde Rijn. Oecologische Kring, Arnhem.

Meer, H.G. van der,; Meeuwissen, P.C. (1989) Emissie van stikstof uit landbouwgronden in relatie tot bemesting en bedrijfsvoering. *Landschap* 6, 19-32.

Melman, D.; Boeschoten, H. (1991) De Relatienota na vijftien jaar. *Natuur en Milieu*, 15, 9-12.

Paassen, A.G. van, (1991) Natuurplan voor het proefbedrijf voor melkvee houderij en milieu. Centrum voor Landbouw en Milieu, Utrecht, 43 p.

Paassen, A.G. van; Terwan, P.; Stoop, J.M. (1991) Resultaatbeloning in het agrarisch Natuurbeheer. Centrum voor Landbouw en Milieu, Utrecht, 84 pp.

Smeding, F.W.; Joenje, W. (1990) Onbespoten en onbemeste perceelsranden in graanakkers. In: *10 Jaar Zonderwijk en VPO*. Dept. of Vegetation Science, Plantecology and Weed Science, Wageningen Agricult. Univ.

Snoo, G. de, (1991) ...

Weinreich, J.A.; Musters, C.J.M. (1989) Toestand van de Natuur: Veranderingen in de Nederlandse Natuur. Min. van Landbouw, Natuurbeheer & Visserij, Den Haag, 241 pp.

Zwieten, M. van, (1990) Set-Aside in Nederland 1/9 1988 - 1/9 1990. Ministerie van Landbouw, Natuurbeheer & Visserij, Den Haag, 37 pp +bijl.

CHANGING VEGETATION AND WEED FLORAS DURING SET-ASIDE AND AFTERWARDS

THOMAS FORCHE

Institut für Pflanzenbau und Pflanzenzüchtung, Bundesallee 50, W-3300 Braunschweig - Germany

ABSTRACT

The results of the vegetation development in 1-, 2- and 3-year set-aside treatments at 5 locations in Lower-Saxony and their influence on the weed floras in the 1st and 2nd year afterwards are presented. The results show, that the number of species is increasing during set-aside periods without fertilization and plant protection. Using a reversible plough, no differences in the weed flora appear in the first year after set-aside; plants and seeds are buried. An increasing number of species could also be established by minimum tillage after set-aside and by using a reversible plough before the second year after set-aside. The "new" species do not require more herbicides for their control.

INTRODUCTION

Short-term set-aside land has existed in Lower-Saxony since August 1986 to reduce the agricultural production. The area increased from 33500 ha during the first year of the "fallow with vegetation cover programme" to 84000 ha during the third year of the set-aside programme. Some 5.5 % of the arable ground or 8 % of the corn-land have been removed from cereal production. Some lands now consist of more than 30 % of set-aside fields. The official regulations specify 1 to 5 year set-aside periods and a sowing (also an ecological succession after winter grain), as well as banning the use of fertilizers and of plant protection agents. These regulations allow the weed flora to develop during set-aside, conditions which do not exist in a conventional crop rotation. So far, there have been no results reported concerning the influence of set-aside - during and afterwards - on the spectrum of species of wild plants.

PLANT PRODUCTION AND LANDSCAPEECOLOGY RESEARCH PROJECT ASSOCIATED WITH THE SET-ASIDE PROGRAMME

Between January 1987 and January 1991 a plant production and landscape-ecology research project on the set-aside programme has been conducted at the Institute for Plant Production and Plant Breeding (Prof. Dambroth) of the Federal Agricultural Research Center in Braunschweig-Völkenrode (FAL), in cooperation with the Institute for Landscape Management and Nature Protection (Prof. Kiemstedt) of the University of Hanover. Within the framework of this research project, four objectives had been pursued:

A - A local, complex analysis of some set-aside treatments concerning the balance of nature and the landscape image at five sites in Lower-Saxony

B - A record and landscape-ecological assessment of the annual set-aside mosaic in three communities

C - To obtain assistance for decision making for the best ecological and economical management of set-aside fields

D - Demonstration of possible cooperations between state-planning, agricultural planning, landscape planning and communities with voluntary and compulsary, short- and long-term set-asides.

The final report of this research project is not yet completed.

For the objective A, the effects of 1-, 2- and 3-year set-aside treatments on the soil, the infiltration water, the plants, selected animal groups, the plant population status as well as the following agricultural use, were compared with the effects of conventional crop rotation and the permanent complete fallow.

This report concerns a single question about one natural resource - the flora: What influence does set-aside have on the spectrum of the weeds during and after periods of set-aside?

TREATMENTS AND METHODS

Field trials were set out on five sites at Hilprechtshausen (Hil), Mahlstedt(Mah), Mecklenhorst (Mek), Völkenrode (Völ) and Warmse (War) on different soils and in different production regions:

TABLE 1. Sites, soils and production regions of field trials.

sites	soils (clay, silt, sand in %)		regions
Hilprechtshausen	clayey silt	(24, 73, 39)	Weser - Leine hilly country
Mahlstedt	humic sand	(3, 11, 86)	Südoldenburg - Mittelweser
Mecklenhorst	sand	(3, 5, 92)	Lößbörde
Völkenrode	loamy sand	(4, 28, 68)	Lößbörde
Warmse	sand	(2, 3, 95)	Heide

The field trials of 3 to 3.5 ha each, consist of 5 blocks next to each other, on an average of 6500 m²:

<table>
<tr><td colspan="3">BLOCK 1
controls
2 treatments</td><td colspan="3">BLOCK 2
2-year set-asides
2 treatments</td></tr>
<tr><td colspan="2">BLOCK 3
rotation area
for the 3
1-year set-asides
in 87/88</td><td colspan="2">BLOCK 4
rotation area
for the 3
1-year set-asides
in 88/89</td><td colspan="2">BLOCK 5
rotation area
for the 3
1-year set-asides
in 89/90</td></tr>
</table>

Fig. 1. Block pattern for the experimental areas.

A grain-rich crop rotation (= CR) and a permanent complete fallow were used as a control in block 1.

The 2-year set-aside treatments in block 2 were:

- ecological succession (= ES 2) without tillage
- red clover (Trifolium pratense)/perennial ryegrass (Lolium perenne) (= RC 2) as a summer sowing in August with 8/8 kg/ha after cultivation.

They were flailed at the minimum of 20 cm in July and September 1988 as well as in July 1989.

In the blocks 3, 4 and 5 three 1-year set-aside treatments were introduced successively:

- ecological succession (= ES 87/ES 88/ES 89) without tillage
- white clover (Trifolium repens) (= WC 87/WC 88/WC 89) as a summer sowing in August with 10 kg/ha after cultivation
- winter vetch (Vicia villosa)/mustard (Sinapis alba) (= VM 87/VM 88/VM 89) as a summer sowing in August with 50/8 kg/ha after cultivation.

All 1-year set-aside variants were flailed at the minimum of 20 cm after the 15th July.

Three 3-year set-aside teatments were investigated in an additional block on the Völkenrode site:

- ecological succession (= ES 3) without tillage
- red clover/perennial ryegrass with flail mowing (= RC 3+) as a summer sowing in August with 8/8 kg/ha after cultivation
- red clover/perennial ryegrass without flail mowing (= RC 3-) as a summer sowing in August with 8/8 kg/ha after cultivation.

Vegetation mapping with details of species density (Braun-Blanquet, 1964) were conducted on six permanent test areas per treatment over three years in April, July and October. Additionally, each treatment was searched at the same time, to investigate the complete spectrum of species. The six 1 m^2 test areas were systematically placed parallel to the centre axis of the 1200 m^2 to 5000 m^2 large treatment areas:

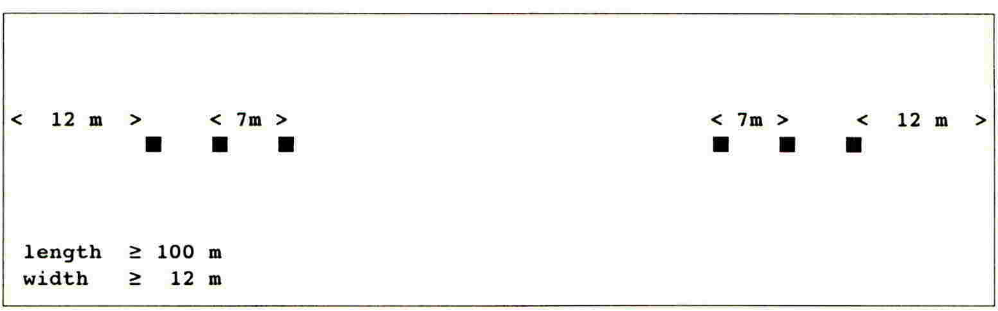

Fig. 2. Systematic positions of the permanent test areas in all treatments.

These test areas remained marked in all treatments at the five sites during the three marketing seasons, from August 1987 to August 1990. Therefore, two sucessive years after 1-year set-asides and one successive year after 2-year set-asides could be investigated, parallel to the conventional crop rotation. The rotation of the 1-year set-aside treatments made it possible to repeat analyses of the first successive year after 1-year set-aside treatments.

In the second successive year after 1-year set-aside treatments the number of germinating wild plants was investigated in the test areas after sowing the main crop.

Plant sociological investigations of weed communities on a minimum area of 25 m^2 were not conducted, because the objective was to investigate the differences in the spectrum of species at and through set-aside as well as the development of single species in the test areas over three years. Typical local weed communities had become impoverished by the intensity of cultivation (Straßburger, 1978; Meisel, 1984; Hofmeister & Garve, 1986; Bolz, 1991) and are replaced more and more after three years of succession by perennial plants. Weed communities require less intensive crop rotations than the best set-aside management.

RESULTS

First, the number of species in the conventional crop rotation on the five sites was examined. In the 15 main crops (5x winter wheat/4x winter rye/3x winter barley/2x winter rape/1x oats) a total of 27 species of wild plants were found, with an average of six species per main crop. Most species occured in the two winter rape treatments with 11 and 12 respectively because of a longer growing period in the summer and because of no herbicide applications during the spring time. No difference was found between other main crops or between the sites. None of the 27 species were endangered ones, all being typical weeds of corn and root crop sites. 161 species in total were recorded on the five sites in the set-aside treatments. 11 of them are registered in the Red Data Book of endangered weeds in Lower Saxony, with 4 or 5 species on individual sites, as Table 2 shows.

TABLE 2. Endangered weed species of set-aside treatments in Lower-Saxony according to Garve (1987).

	scores of Red Data Book	appeared at site				
Agrostemma githago	1	Völ	Mek	---	---	---
Anthemis arvensis	(3F)	Völ	Mek	War	---	Mah
Bromus arvensis	3	---	---	---	---	Mah
Euphorbia exigua	(3F)	---	---	War	Hil	---
Papaver rhoeas	(3F)	Völ	Mek	War	Hil	---
Ranunculus arvensis	2	---	---	---	---	Mah
Sheradia arvensis	2F, 3	---	---	---	Hil	---
Silene noctiflora	3	Völ	Mek	---	---	---
Stachys arvensis	3	---	---	---	---	Mah
Veronica praecox (*)	2	---	Mek	War	Hil	---
Veronica verna (*)	2	Völ	---	War	---	---
total number per site:		5	5	5	4	4

(Legend of Table 2 on following page.)

Legend:

0	= missing	1	= endangered to missing
2	= strong endangered	3	= endangered
F	= score only for flat country	(3F)	= suspected score
(*)	= main distribution area outside of fields		

Forty nine species of the total found were limited to one site. Of these locally specific species, 43 were growing in ecological succession treatments. The site factors are consequently more effective in ecological succession than in summer sowing treatments.

Fig. 3 shows the average number of species of the set-aside treatments compared with the conventional crop rotation. This indicates that in the 2-year ecological succession (ES 2), the largest number of plant species are to be found. On average 55 (SE 9,5) species were found in ES 2 treatments. The spectrum of species in these treatments is nine times larger compared with the conventional crop rotation (CR). On average, 38 (SE 9,8) species were found in the 1-year ecological succession (ES 1). This number did not change when the 1^{st} year data for ES 2 was included. The summer sowing treatments (WC 1 and VM 1) did not show a significant difference in the number of species. Of all the set-aside treatments, the 2-year treatments with summer sowing of red clover/perennial ryegrass supported the lowest number of species on all sites. However, there were more than three times the number of species compared with the 15 conventional main crops.

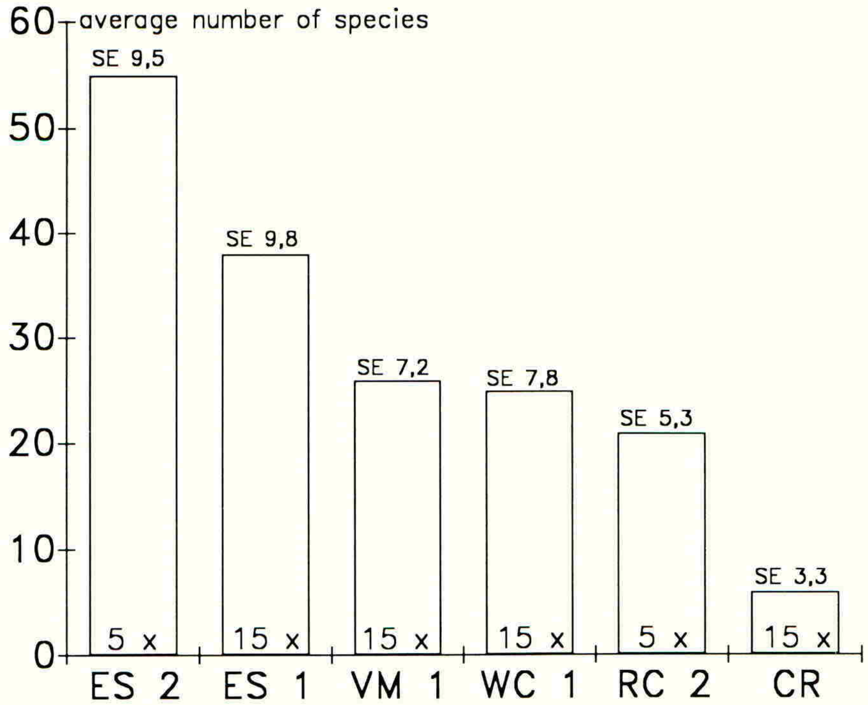

Fig. 3. Average number of species in 1- and 2-year set-aside treatments and in the conventional crop rotation.

In the 3-year ecological succession at Völkenrode, 63 species were recorded. This indicates that in an unimpaired succession, even in the third year, an increase in species number can be expected. In the 3-year red clover/perennial ryegrass treatments the number of species was 29 without flailing and 17 with two flailings per year.

Following the set-aside treatments, four sites were ploughed. Inversion tillage and conventional herbicide application did not allow a conclusion to be drawn regarding the spectrum of species in the first main crop after set -aside. On one site a cultivator and a rotavator were used after ES 2 and RC 2. Following a shallow tillage the ES 2 was characterised in the winter wheat in June by 3 - 5 % cover with loose silky-bent (*Apera spica-venti*). In winter wheat, the number of weed species was 13 after ES 2, 16 after RC 2 and four after winter rape in the conventional crop rotation. The same tendency of increasing numbers of species following set-aside was found in second main crops after a repeated ploughing.

In Table 3, the species in the crop rotation ES 1/winter rye/winter rye on the site at Völkenrode are listed in alphabetical order. Their occurence in the particular year is marked by a row of stars.

TABLE 3. List of species in Völkenrode during 1-year ecological succession and in the following two winter rye crops.

	ES 1	↓ plough winter rye	↓ plough winter rye
Anagallis arvensis	*************		
Anthemis arvensis	*************		
Apera spica-venti	*************		
Aphanes arvensis			*************
Arabidopsis thaliana	*************		*************
Capsella bursa-past.	*************	*************	
Chamomilla recutita	*************		*************
Chenopodium album	*************		*************
Chenopodium rubrum	*************		
Cirsium arvense	*************	*************	*************
Conyza canadensis	*************		*************
Epilobium angustifo.	*************		*************
Geranium pusillum	*************		*************
Hypericum perforatum	*************		
Lamium amplexicaule	*************		*************
Lolium perenne	*************		
Matricaria perforata			*************
Myosotis arvensis	*************		*************
Papaver lecoqii	*************		
Phacelia tanacetifo.	*************		
Plantago major	*************		
Poa annua	*************	************	*************
Polygonum aviculare	*************		
Senecio vernalis	*************		
Senecio vulgaris	*************	************	*************
Sisymbrium officina.	*************		
Sonchus arvensis	*************		

(Continuation on following page.)

	ES 1	↓ plough	winter rye	↓ plough	winter rye
Stellaria media	*************		************		*************
Taraxacum officinal.	*************		************		*************
Thlaspi arvense	*************				
Trifolium arvense	*************				
Trifolium repens			************		
Veronica arvensis	*************				
Vicia hirsuta	*************				*************
Viola arvensis	*************		************		*************
Total number of species:	36		8		17

The nomenclature is according to Hanf, 1982 and Rothmaler, 1978.

The differences between the total number of species (Table 3) in each year showed a tendency, found in all ES 1 treatments which had been ploughed twice. After ploughing and before the first following crop, only common weeds were found. There was no difference in the spectrum of species to the conventional crop rotation. After ploughing before the second following crop there were twice the number of species, while only 6 to 8 species were found in the conventional winter rye.

After 1-year summer sowing treatments, the number of species also declined after ploughing before the first following crop, compared with conventional rotation. However, there were fewer species after ploughing before the second following crop.

The results of the spectrum of species were supported by the counting of wild plant seedlings before the first herbicide application. The counts were conducted on 24th of November 1989 in the winter wheat and on 29th of November in winter rye (Table 4).

TABLE 4. Average number of non-crop seedlings per m^2 in winter wheat at Mecklenhorst and in winter rye at Völkenrode in November 1989.

after:	Number of seedlings (m^2) in winter wheat	winter rye
CR	11	1
ES 2	14	2
RC 2	13	3
ES 88	9	1
WC 88	6	1
VM 88	12	2
ES 87	1500	1112
WC 87	860	516
VM 87	930	662

Table 4 shows that the numbers of non-crop seedlings at both sites in the conventional crop rotation (CR) and in the 1- and 2-year set-aside treatments, ploughed in September 1989, were similar. In the second year after 1-year set-aside treatments (from August '87 to August '88) the number of seedlings ranges from 516 to 1500 m^2, which would result without doubt in crop yield reduction.

On all sites the maximum seedling densities were recorded in previous ES treatments. After the usual herbicide applications, no differences were found between previous set-aside in the vegetation records made in April 1990. Only the vegetation assessments in July 1990 showed the above mentioned differences in the spectrum of species.

Table 5 shows the cover scores of the weed flora according to Braun-Blanquet (1964) in the second successive year after ES 87 at Völkenrode. Nine of the 11 species in the test areas are typical weeds of arable land. The occurrence of the species Conyza canadensis and Epilobium angustifolium is explained by the previous set-aside. A few specimens were found of the six species growing only outside of the test areas.

TABLE 5. Cover scores, according to Braun-Blanquet (1964), for the weed flora in July 1990 in the second successive year of the treatment ES 87 at Völkenrode.

	test areas					
	1	2	3	4	5	6
Aphanes arvensis	-	-	-	r	+	r
Chamomilla recutita	-	-	-	r	r	-
Chenopodium album	*	*	*	*	*	*
Chenopodium rubrum	*	*	*	*	*	*
Cirsium arvense	r	-	+	-	-	-
Conyza canadensis	r	1	r	+	1	r
Epilobium angustifo.	-	+	-	+	1	-
Lamium amplexicaule	r	+	-	+	+	+
Myosotis arvensis	*	*	*	*	*	*
Poa annua	-	-	-	+	-	-
Polygonum aviculare	*	*	*	*	*	*
Senecio vernalis	*	*	*	*	*	*
Senecio vulgaris	-	r	r	+	r	-
Stellaria media	r	+	-	+	+	+
Taraxacum officinale	*	*	*	*	*	*
Vicia hirsuta	-	-	r	-	r	-
Viola arvensis	1	3	2	3	2	2

Legend:
- = not in the test area
r = 1-3 specimens
+ = some specimens, less than 1 %
1 = 1 - 5 % cover scores
2 = 5 - 25 %
3 = 25 - 50 %
4 = 50 - 75 %
5 = 75 - 100 %
* = only outside the test areas

At the same time the following seven species were found in the winter rye of the conventional crop rotation at Völkenrode:

Convolvulus arvensis
Poa annua
Stellaria media
Viola arvensis
Lamium amplexicaule
Polygonum aviculare
Taraxacum officinale

Because of the naturally disjunct distribution of species on a field, any additional species can be traced back with a high probability but not certainty to the previous set-aside treatments.

INTERPRETATION OF RESULTS

The results show, that the number of species is increasing during set-aside periods without fertilization and plant protection. Using a reversible plough, no differences in the weed flora appear in the first year after set-aside; plants and seeds are buried. An increasing number of species could also be established by minimum tillage after set-aside and by using a reversible plough before the second year after set-aside. The "new" species do not require more herbicides for their control. Neither is a decrease in yield to be expected. In only one case the couch grass (Agropyron repens) developed in an ES 2 from existing 3 to 5 specimens/m² to a coverage score of 15 to 35 %. The following main crop was winter rape. Without couch grass control the crop yield loss was about 10 %.

The results of the changing weed floras during and after set-aside are one section in the research project studying set-aside in Lower-Saxony. A comprehensive view of all the results is thrusting the changing weed floras after set-aside into the background for decision making (Forche et al., 1990). The numbers of herbicide applications are not increasing, but the crop yield does, if there are no errors in crop husbandry. At the Völkenrode site, the mechanical control of seedlings in the second following year have been investigated since August 1991.

With their decisions, the farmers are responsible for the effects of set-aside in the whole ecosystem and the landscape image.

As a consequence of the date of acceptance of set-aside applications, the farmers did not know at harvest time whether their fields were in the set-aside programme or not. The concessions were given so late that even an autumn cultivation was not possible.

So far, the following recommendations for a set-aside management are given after interim results (Forche et al., 1990):

- summer sowing directly after harvesting, ecological succession if possible
- crop-mixture instead of single-crop farming, thereby
  * flourishing times in autumn and late spring
  * legumes - if necessary - graduated to the valuation index of field
- returning to a conventional crop rotation in spring after 18 months or more.

These recommendations take recultivation into account after 1 to 5 years (if possible at least 18 months), without the need for additional herbicide applications.

REFERENCES

Bolz, Dorothea (1991). Bielefelder Ackerrandstreifenprogramm erfolgreich angelaufen - Ergebnisbericht 1989-1990. LÖLF-Mitteilungen **1/91**, 30-34

Forche, Th., Dambroth, M. & C. Sommer (1990). Praxisrelevante Zwischenergebnisse der Begleitforschung zum Grünbracheprogramm bzw. zur Flächenstilllegung in Niedersachsen.

1. Norddeutsche Naturschutzakademie (NNA) Berichte, **3**, H. 2, pp. 87-92
2. Hess. Minist. für Landwirtschaft, Forsten u. Naturschutz (HMLFN) - "Ökologie Forum Hessen", pp. 46-51

Garve, E. (1987). Rote Liste der in Niedersachsen gefährdeten Ackerwildkräuter. Informationen des Naturschutzes Niedersachsen, **7**, Nr. 4, pp. 29-34

Hanf, M. (1982). Ackerunkräuter Europas mit ihren Keimlingen und Samen 2. Auflage, München, 496 pp.

Hofmeister, H. & E. Garve (1986). Lebensraum Acker. Hamburg/Berlin, Parey, 272 pp.

Meisel, Klaus (1984). Landwirtschaft und "Rote Liste" Pflanzenarten. Natur und Landschaft, **59**, (7/8), 301-307

Rothmaler, Werner (1978). Excursionsflora - Gefäßpflanzen. 9. Auflage, Volk und Wissen Volkseigener Verlag Berlin, 615 pp.

Straßburger, E. (1978). Lehrbuch der Botanik. Jena, Fischer Verlag, pp. 887 -943

EFFECTIVENESS OF SOWN COVERS FOR THE MANAGEMENT OF WEEDS IN SET-ASIDE FALLOWS : THE BUSH TRIALS

N.M. FISHER, D.H.K. DAVIES

SAC, Crop Systems Department, Bush Estate, Penicuik, Midlothian EH26 OPE

ABSTRACT

Plots were set up at two sites near Edinburgh after harvest 1988 to compare sown covers of ryegrass, ryegrass and clover and red fescue with undisturbed and unsown fallows. Cultivation to produce a seedbed stimulated the germination of annual weeds and made the sown plots more weedy than unsown in the first summer. Nevertheless the sown covers have given effective control of most biennial or perennial species which have succeeded the annuals and especially of a very heavy and unsightly infestation of Cirsium vulgare (spear thistle) on one site. An exception to this has been poor control of Elymus repens (common couch) at the other site. The addition of white clover to ryegrass has greatly improved ground cover and the suppression of most weeds. We conclude that the sowing of ryegrass or a ryegrass-clover mix is desirable for weed management in set-aside fallows.

INTRODUCTION

At the time set-aside was first offered in the UK, summer 1988, very little was known about the vegetation likely to develop on old arable land and on how it might best be managed whether for amenity, wildlife habitat, or simply for easy restoration to arable farming. The rules required that the set-aside land should have a vegetative cover but did not require anything to be sown if the developing indigenous vegetation provided adequate cover. Fertilisers, organic manures, insecticides and fungicides were not to be applied and herbicides were only to be used with special permission. Mowing was required at least once per year and the UK Weeds Act 1959 continued to apply.

The trials at Bush were laid down after harvest 1988 to compare three different sown covers with unsown and undisturbed plots. At the time of writing, the treatments are in their third summer and will continue to be cut and recorded for five full years. This paper concentrates on the effectiveness of the sown covers in reducing the occurrence of weeds which might threaten adjacent or subsequent crops, might make the land difficult to return to arable farming or might render the farmer in breach of the Weeds Act by supporting species of Rumex, Cirsium or Senecio jacobaea.

MATERIALS AND METHODS

The sub-set of treatments used for the data presented in this paper is as follows:

- US Natural regeneration: uncultivated and unsown
- RG Cultivated and sown with perennial ryegrass (20 kg/ha cv. Wendy)
- RG+WC Cultivated and sown with perennial ryegrass and white clover (20 kg/ha cv. Wendy + 2 kg/ha cv. Grasslands Huia)
- RF Cultivated and sown with red fescue (20 kg/ha cv. Logro).

Hill Field on the Edinburgh University Farm has a long history of arable cropping and 2 hectares were chosen for the main site at map reference NT246655. It is on the east-facing slope of the Pentland Hills, rising steeply from 210 m ASL to 240 m and is bounded to the south by a mature, mainly coniferous shelterbelt. There are two replicates, arranged so that each treatment occurs once beside the shelterbelt and once in midfield; once in the lower relatively flat part of the field with a plot size of 45x15 m and once in the steep upper part with 45 x 10 m plots. This site was heavily grazed by rabbits in the first year and more recently, deer have been frequently seen. A second minor site was located close to the Bush Estate campus at map reference NT243368 and 190m ASL. This field had been in grass between 1985 and 1987. There is a single replicate with plots 45x15 m and abutting at their north end onto a shrubby bank and cypress hedge.

After harvest of spring barley in September 1988, the stubble was untouched through the winter. All but the unsown plots were subject to a shallow cultivation on 14 April 1989. The appropriate cover species were sown into a moist seedbed on the same day. All of the treatments described here have been subject to a three-cut regime, early June, early August and early October, applied with a tractor-mounted "Votex" rotary cutter, and with the cuttings left lying on the field. Cutting height has been 100 mm for the first annual cut and 60 mm for subsequent cuts.

Permanent quadrat points were defined on a rectangular grid and a 500 x 500 mm (0.25 m2) quadrat placed at each point. Estimated ground cover by each species was recorded. Results presented in the paper are for midfield quadrats only, that is those more than 12 m from the shelterbelt in Hill Field or the hedge at Bush.

RESULTS

Ground cover and number of species (Hill field)

The sown grasses were rather slow to develop (Table 1), with the fescue achieving only 12% ground cover by August 1989, four months after sowing. White clover developed most rapidly and overgrew the ryegrass in the RG+WC treatment. Not until November 1989 was a reasonable cover of sown grasses achieved. Since October 1990, fescue has tended to give better cover than ryegrass but still well below 50% ground cover, limited apparently by nitrogen deficiency in the case of ryegrass and by the slow decomposition of its litter in the case of fescue. Clover has maintained its dominance in the RG+WC plots.

TABLE 1. Frequency (F, % of 36 quadrats) and ground cover (G, %) of the sown species; total number of species and total ground cover in Hill Field.

Treatment	Aug 89		Nov 89		May 90		Oct 90		May 91	
	F	G	F	G	F	G	F	G	F	G
	<u>Lolium perenne</u> (perennial ryegrass)									
RG	100	48.2	100	59.6	100	55.8	100	23.9	100	29.6
RG+WC	100	17.2	100	28.6	100	14.9	100	25.1	100	32.5
	<u>Festuca rubra</u> (red fescue)									
RF	97	12.2	100	47.2	100	39.0	92	35.1	100	40.6
	<u>Triflolium repens</u> (white clover)									
RG+WC	100	49.7	100	62.4	100	83.1	100	68.5	100	50.6
	No of species in quadrats									
US	14		15		18		16		22	
RG	11		10		12		13		13	
RG+WC	14		4		5		6		8	
RF	12		13		12		10		9	
	Total ground cover of all species									
US		36.5		42.6		66.0		71.6		77.3
RG		72.4		63.4		66.3		55.2		58.8
RG+WC		85.2		91.2		99.2		95.6		83.8
RF		57.4		64.4		56.1		66.8		63.3
SED		12.3		3.1		5.8		5.6		5.1

The number of species recorded in quadrats has been greater in the unsown treatment than in any of the sown treatments and does appear to be increasing slowly. There has been little difference in species number between RF and RG but some indication that the poor early performance of the fescue may have allowed rather more species to colonise than the ryegrass. The clover has been very effective in eliminating many of the species present in August 89. Ground cover by all species in the unsown treatment was very low during the summer of 1989. The contribution of clover has ensured ground covers in RG+WC consistently and usually significantly greater than in any other treatments.

TABLE 2. Frequency (F, % of 36 quadrats) and ground cover (G, %) of the important annual weedy species in Hill Field.

Treatment	Aug 89		Nov 89		May 90		Oct 90		May 91	
	F	G	F	G	F	G	F	G	F	G
	Poa annua (annual meadowgrass)									
US	69	17.0	97	13.7	100	35.8	97	24.2	94	25.7
RG	44	1.0	69	1.6	81	2.7	31	0.6	22	0.6
RG+WC	33	0.9	3	0.1					6	0.1
RF	53	3.7	89	4.9	92	8.3	3	0.1		
	Senecio vulgaris (groundsel)									
US	78	4.8	100	12.2	69	2.8	42	0.9	17	0.3
RG	14	0.2	6	0.1	8	0.2	3	0.1		
RG+WC									6	0.1
RF	6	0.1	47	1.5	44	1.2				
	Capsella bursa-pastoris (shepherd's purse)									
US	69	6.4	69	4.6	58	2.3			8	0.3
RG	100	18.3	8	0.2						
RG+WC	89	8.6								
RF	83	10.4	8	0.1						
	Stellaria media (common chickweed)									
US	28	1.5	36	2.1	44	2.0	14	0.3	19	0.4
RG	42	2.4	14	0.2			19	0.4	3	0.1
RG+WC	31	3.5							6	0.1
RF	89	13.9	39	0.8	3	0.2				
	Chamomilla suaveolens (rayless mayweed)									
US	22	1.3	31	1.0	33	1.5				
RG	31	0.8	3	0.1						
RG+WC	33	4.2								
RF	53	10.1								
	Hordeum vulgare (volunteer barley)									
US	6	0.1	17	0.2	28	0.4				
RG							absent from quadrats			
RG+WC	3	<0.1								
RF	6	0.1								
	Sonchus spp (annual sowthistles)									
US					58	7.4	22	0.7	28	0.6
RG							3	<0.1	3	<0.1
RG+WC							absent from quadrats			
RF							11	0.2	8	0.1
	Galium aparine (cleavers)									
US							3	<0.1	14	0.4
RG									3	0.1
RG+WC							absent from quadrats			
F							absent from quadrats			

Annual species

Poa annua has been an important species in the unsown plots (Table 2) tending to be more common after wet weather and to die out during drought.

Though common in RG and RF, it has never contributed any great ground cover. Senecio vulgaris, mainly germinating in the autumn of 1988, was common on the unsown plots up to May 1990 but little has been seen since.

Germination of Capsella bursa-pastoris was stimulated by the cultivation before sowing and, being taller than the seedling grasses, appeared to dominate sown plots until cut in August 1989. The clover in RG+WC did suppress it to some extent. Stellaria media and Chamomilla suaveolens behaved rather similarly but were less conspicuous. None of these species has contributed much to ground cover of sown plots since the spring of 1990, though they still occur in the unsown plots.

Volunteer barley appeared in the straw rows in autumn 1988 but was grazed off by rabbits or uprooted by birds. Its occurrence after the treatments were imposed was too low to draw any conclusions about the effect of treatment except that it may have persisted longer in the unsown than in sown treatments.

Sonchus species and Galium aparine did not appear in the quadrats until October 1990 and then mainly in the unsown treatment. They are the only annual species to have increased in importance as time has passed.

Biennial and perennial species

Cirsium vulgare (with some C. arvense) has been the most important species on the unsown plots, starting with scattered plants but now visually dominant at about 20% ground cover and most unsightly (Table 3). Rumex obtusifolius has also tended to increase in the unsown plots.

A lower story of ground cover in unsown plots is provided by Ranunculus repens and Trifolium repens (along with P annua). Both, but particularly the T. repens, have increased over time. R. repens has not been important in the sown plots but T. repens has, appearing to spread vegetatively from a very few seedling plants within each plot but now reaching the point where large parts of the RG plots are little different from RG+WC.

Rubus spp and Epilobium montanum are largely confined to the unsown plots but are increasing only slowly whereas Taraxacum officinale is common in RF as well as the unsown plots. Acer pseudoplatanus, the only tree species recorded in quadrats, has occurred in unsown and RG plots, but at fluctuating levels.

Differences at the Bush campus plots

This site differs from Hill field principally in that perennial grasses, rather than Cirsium, Rumex and Ranunculus have dominated the unsown plots, giving a visually much more acceptable ground cover and presumably reflecting the short time since this area was in grass. Polygonum aviculare, S. vulgaris and H. vulgare germinated as a result of cultivation but have since disappeared (Table 4). Other annuals such as P. annua were present at first but have tended to disappear with time, at least in the sown plots. Phleum pratense, Lolium perenne and Elymus repens have been responsible for most of the ground cover in the unsown plots. E repens has also been important in the sown plots. Even more than in Hill field, volunteer T. repens has come into the RG and RF plots but has remained unimportant in the unsown plot.

TABLE 3. Frequency (F, % of 36 quadrats) and ground cover (G, %) by biennial and perennial species in Hill Field

Treatment	Aug 89		Nov 89		May 90		Oct 90		May 91	
	F	G	F	G	F	G	F	G	F	G
Cirsium vulgare (spear thistle)										
US	14	2.1	86	4.4	89	4.6	97	20.3	97	22.0
RG	8	0.8	11	0.1	6	0.8	22	0.4	14	0.3
RG+WC	3	0.1	8	0.5	6	1.0	3	0.2		
RF			3	<0.1	53	2.4	44	2.1	25	1.0
Rumex obtusifolius (broad-leaved dock)										
US			8	0.6	22	2.0	22	1.8	19	2.5
RG			3	<0.1	3	0.3	3	<0.1	3	<0.1
RG+WC					8	0.2	11	1.3	8	0.6
RF					8	0.2	6	0.1	6	0.3
Trifolium repens (white clover)										
US	8	0.1	8	1.1	28	1.8	53	15.3	61	14.9
RG	8	0.1	33	1.3	53	5.6	81	27.8	83	27.0
RG+WC	sown species, see table 1									
RF	19	4.6	42	8.9	50	15.6	78	25.4	81	20.0
Ranunculus repens (creeping buttercup)										
US	3	0.3	8	1.3	8	1.1	17	2.5	14	2.5
RG	3	<0.1	3	0.2	3	0.3	3	0.6	3	0.6
RG+WC	absent from quadrats									
RF			3	0.1	3	0.1	3	0.1	3	0.1
Rubus spp (brambles)										
US			3	0.1	3	0.1	3	0.1	6	0.1
RG, RG+WC, RF	absent from quadrats									
Epilobium montanum (broad-leaved willowherb)										
US					31	0.6	25	0.5	33	1.1
RG							3	<0.1		
RG+WC, RF	absent from quadrats									
Taraxacum officinale (dandelion)										
US			3	<0.1	11	0.3	31	1.5	61	3.4
RG					3	0.1	3	<0.1	11	0.1
RG+WC					3	0.1	3	<0.1	3	0.1
RF			3	0.1	17	0.5	22	1.3	25	1.4
Acer pseudoplatanus (sycamore)										
US					22	0.4	6	0.1	17	0.3
RG					31	0.6	6	0.1	6	0.1
RG+WC	absent from quadrats									
RF					3	0.1				

TABLE 4. Frequency (F, % of 15 quadrats) and mean ground cover (G, %) of some important species in Bush campus plots.

Treatment	Aug 89 F	Aug 89 G	May 90 F	May 90 G	Oct 90 F	Oct 90 G	May 91 F	May 91 G
	Polygonum aviculare (knotgrass)							
US					absent from quadrats			
RG	53	5.6						
RG+WC	40	1.1						
RF	87	5.5						
	Senecio vulgaris (groundsel)							
US	47	1.3	13	0.3	17	0.3		
RG	67	0.9	7	0.1			7	0.1
RG+WC	40	1.3						
RF	80	2.8	20	0.2				
	Poa annua (annual meadowgrass)							
US	93	19.9	93	11.2	92	8.2	93	14.5
RG	100	17.3	93	12.1	17	0.4	40	3.2
RG+WC	13	0.3					40	1.5
RF	73	9.2						
	Hordeum vulgare (volunteer barley)							
US					absent from quadrats			
RG	20	0.5						
RG+WC	20	0.3						
RF	33	1.5						
	Phleum pratense (Timothy)							
US	87	20.9	100	18.7	67	11.4	100	17.1
RG	27	1.4	27	1.6	17	0.3	33	2.5
RG+WC	33	0.9	73	2.9	17	2.1	47	3.0
RF	40	2.1	40	2.2	25	1.3	33	1.3
	Lolium perenne (perennial ryegrass)							
US	87	17.5	80	9.1	92	16.4	100	22.9
RG	(100	59.7)	(100	35.4)	(100	41.7)	(100	37.3)
RG+WC	(100	12.5)	(100	16.5)	(100	33.0)	(100	31.4)
RF	33	6.5			17	1.0	60	10.7
	Elymus repens (couch)							
US	67	8.3	47	4.7	25	8.0	47	3.7
RG	27	2.8	40	6.8	67	4.6	53	4.2
RG+WC	60	2.3	40	1.7	83	7.8	73	6.9
RF	53	7.9	40	2.9	58	8.3	73	6.1
	Trifolium repens (white clover)							
US			7	0.1			13	5.4
RG			67	23.5	100	38.3	100	42.9
RG+WC	(100	78.9)	(100	76.1)	(100	51.9)	(100	50.0)
RF			80	30.0	92	12.3	100	16.8

DISCUSSION

A number of annual weeds such as C. bursa-pastoris in Hill field and P. aviculare in the Bush campus site were stimulated to germinate by seedbed cultivation and this, together with the slow early growth of the sown grasses, made the sown treatments more weedy than the undisturbed plots in the first summer. These annual species have since disappeared but there was undoubtedly a massive return of seed of C. bursa-pastoris in Hill field. This weed could be a problem to control in any subsequent non-cereal crop. Seedbank analysis, planned for later in the project, should add to our knowledge of such weed seed return. The only sown species which competed with the annual weeds was white clover which apparently reflected the very poor nitrogen status of the top layers of soil in which the sown grasses were rooting.

All of the sown treatments have given quite remarkable control in Hill Field of C. vulgare which is an injurious weed under the Weed Act. On the sown plots, the weed apparently failed to establish successfully from seed at the time it was able to multiply rapidly on the open ground of the unsown plots. R. obtusifolia was not quite so well controlled but still less of a problem in sown than in unsown plots.

E. repens in the Bush campus plots has undoubtedly multiplied in the sown treatments and it remains to be seen whether the decline over the winter of 1990-91 is the beginning of a trend in which the other grasses will suppress it. Irrespective of treatment, control of E. repens with a glyphosate product approved for sward destruction will be needed at the end of any set-aside period before the land is restored to cropping.

We conclude as follows:

* a sown cover is of considerable benefit for the control of most weed problems in land set-aside for longer than one year, particularly if the land has been in arable cropping for many years so that there are few pasture grasses in the seedbank

* because of the absence of fertiliser, clover is often the most competitive species and should be included in the seed mixture at least for short-term set asides

* except possibly where set-aside land is being used as an entry for organic farming, the three-cut regime will provide adequate management of most weed problems if the land is sown with grass or grass-clover.

Acknowledgements

Funds for this work have been made available by the Scottish Office Agriculture and Fisheries Department with a small contribution from the Nature Conservancy Council. We are grateful to G Wilson for his painstaking recording and to A T Cleland for management of the plots.

SOIL PROPERTIES AND PLANT NUTRIENTS AFFECTING THE OCCURRENCE OF *POA ANNUA*, *STELLARIA MEDIA* AND *VIOLA ARVENSIS* ON ARABLE LAND

C. ANDREASEN, J.E. JENSEN & J.C. STREIBIG

The Royal Veterinary and Agricultural University, Department of Agricultural Sciences, Section of Crop Science, Thorvaldsensvej 40, DK-1871 Frederiksberg C, Denmark.

ABSTRACT

The distribution of three dominating weed species in response to eight crops and seven edaphic factors was evaluated using multiple linear logistic regression with adjustment for over-dispersion. The edaphic factors were pH, P, K, Mg, Mn, organic matter and clay content. Crop type and sampling year were used as class variables. *Viola arvensis* was favoured by decreasing potassium and clay content. Crop type and potassium affected the occurrence of *Stellaria media*. The occurrence of *Poa annua* was influenced by crop type, organic matter with a significant interaction. Graphical methods are used to illustrate the results. The response of the weed flora to changing land use is discussed.

INTRODUCTION

The purpose of this paper is to relate the distribution of weeds to soil properties after adjusting for the influence of crop type and sampling year. As all explanatory variables are considered simultaneously, the method of analysis makes it possible to assess the effect of a soil property independently of all other explanatory variables in the analysis.

MATERIALS AND METHODS

This paper presents analysis of 8 crops in 316 fields throughout the years 1987-1989 (Andreasen *et al.*, 1991). The analyses were carried out in July and August just before harvest so that the weeds had been affected by the respective crops during the growing season. The fields, randomly chosen each year, were in conventional agricultural use and located throughout the country. The analysed fields were unsprayed with herbicides in the sample year, so the incidence of weed species reflected the potential of the soil seed bank.

The frequencies of weeds species were recorded by listing the presence or absence of the species in ten randomly selected circular sample plots of 0.1 m^2 within each field (Raunkiær, 1934). The sample plots were never located in the headland, which often differs from the rest of the field.

Soil samples were taken from the uppermost twenty centimeters and analysed for clay content, organic matter based on loss on ignition, pH, available phosphorous, exchangeable potassium, magnesium and manganese (Andreasen *et al.*, 1991).

Due to the discrete nature of the frequency data, multiple logistic regression models were used (Eq. 1):

$$\text{logit}(p) = \ln[\frac{p}{(1-p)}] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \ , \qquad (1)$$

where p is the probability of finding a species in a single sample plot within a field. β_0 is an intercept term and the parameters, $\{\beta_1, \beta_2, \ldots, \beta_n\}$, describe the effects of the regression variables, $\{x_1, x_2, \ldots, x_n\}$.

After being adjusted for over-dispersion, the multiple logistic regression models tested relations between weed distribution and crop type, sample years and soil properties (Andreasen *et al.*, 1991). In order to avoid some fields with extreme values having an undue influence on the regression parameters, the edaphic variables were log-transformed. The frequencies of weed species were analysed in response to the nine variables by a stepwise regression analysis (a backward elimination method (Weisberg, 1985)). By this method we were able to reduce the models so they only consisted of statistically significant explanatory variables. After reducing the model, it was extended with an interaction variable.

RESULTS

The soil properties were to a certain extent mutually correlated, but no estimated correlation coefficients were greater than ± 0.5 and consequently there was no reason to omit any soil properties in order to avoid collinearity (Weisberg, 1985).

Figures 1 and 5 show the observed values in relation to significant regression parameters for *V. arvensis* and *S. media*, respectively. It is obvious that the range of frequencies in fields having almost the same value of a soil property vary from 1 to 0. We have accounted for this extreme variation by including an over-dispersion parameter in the statistical analyses (Andreasen *et al.*, 1991). This variation, which cannot be explained either by the explanatory variables or by the binomial variance, might be due to the history of the fields (crop rotation, previous use of herbicides, soil cultivation, etc.).

In spite of this large variation the statistical analyses (Table 1) showed highly significant effects of some of the factors as illustrated in Figs. 3, 6 and 7. Due to this extra-binomial variation, the exact values of the slope of the curves carry little information.

TABLE 1. *P*-values for statistically significant regression parameters. The *P*-values are derived from sequential tests of the models.

	Crop type *A*	Clay content *C*	Potas-sium content *K*	Organic matter *L*	Inter-action *A*L*
Poa annua	0.0001			0.0000	0.0131
Stellaria media	0.0000		0.0316		
Viola arvensis		0.0001	0.0012		

DISCUSSION AND CONCLUSION

Viola arvensis was significantly affected by clay content and exchangeable potassium content in the soil (Table 1). Figure 1 illustrates the relation between frequencies of *Viola arvensis* and the two soil properties. The observed values were mainly concentrated on relatively small values of potassium in Fig. 1. Nevertheless the 316 predicted frequencies in Fig. 2 show that the predicted response surface in Fig. 3 is relatively well-defined. Figure 3 clearly illustrates a curvilinear response surface. This response surface is derived from the reduced multiple regression model (Eq. 2):

$$\text{logit}(p) = \beta_0 + \beta_1 \ln(K) + \beta_2 \ln(C) \ , \qquad (2)$$

where K denotes potassium and C clay content. This response surface of the transformed data is a plane (Fig. 4). Transforming Eq. 2 (Fig. 4) back to original frequencies, we get Eq. 3 (Fig. 3):

$$p = \frac{\exp[\beta_0 + \beta_1 \ln(K) + \beta_2 \ln(C)]}{1 + \exp[\beta_0 + \beta_1 \ln(K) + \beta_2 \ln(C)]} \qquad (3)$$

The estimates of β_1 and β_2 were negative, which means that decreasing content of both factors favour the occurrence of *V. arvensis*. The effect of decreasing available potassium is more important when the clay content of soils is relatively small than in soils with relatively high clay content (Fig. 3).

Stellaria media was significantly affected by crop type and potassium content (Fig. 6). Increasing content of exchangeable potassium in the soil generally favored the occurrence of *S. media*. This correspond to other investigations (Korsmo, 1954; Kofoed, 1978) that the potassium content expressed in per cent of dry matter in *S. media* is high compared with other weed and crop species.

A significant effect of crop type may be a result of competition for light, nutrients and other growth factors, but may also be confounded with soil treatment, preceding crops and other agronomic factors that characterize modern crop growing. The reason why *S. media* is particular frequent in rape is probably due to the time of sampling. In August the rape plants have ripened and thus allowing high light interception at the soil surface; this will facilitate renewed *S. media* establishment.

Increasing content of exchangeable potassium in the soil favoured *Stellaria media*. The potassium content is to some extent affected by the fertilizer level. The consumption of commercial potassium fertilizer per hectare has been rather constant since the beginning of the eighties (about 43 kg ha^{-1}) (Anonymous, 1990), and there is no reason to believe that the consumption will increase in Denmark over the next decade. On the contrary, statuary legislation to ensure optimal use of farm manure to prevent leaching and pollution of drinking water (Anonymous, 1988a) will probably reduce the potassium content in some areas with sandy soils in the western part of Denmark, where animal husbandry dominates. This legislation will perhaps gradually reduce the competitiveness of *S. media* and favour *V. arvensis* in these areas during the next decade.

Crop type and organic matter affected the occurrence of *Poa annua* and a significant interaction also was found (Table 1). Figure 7 shows the estimated frequencies in relation to organic matter. Loss on ignition is a crude way to measure organic matter content in the soil in that a significant effect of this factor, does not necessarily mean that organic matter influences the weed distribution. It might be the water holding capacity of the soil, which is closely associated with the organic matter. On heavy soils the loss on ignition can be quite large due to the high content of hygroscopic and chemically bound water. On very calcareous soil types great loss on ignition can be caused by large amounts of $CaCO_2$. Soil types with large ignition loss, be it organic or clay soils, are generally quite moist and frequently poorly drained.

Increasing organic matter has a positive effect on the frequencies of *Poa annua* in all crop types (Fig. 7). The slope of the curves indicates how important the organic matter is for the occurrence of the species. It is obvious that the curves fell into two significantly different groups that illustrate the significant interaction between crop type and organic matter. One group of curves with shallow slopes consisted of sugar beets for sugar production, spring barley and rye, and the other group of curves with steep slopes consisted of the other crop types. In the first group, *Poa annua* only occur with relatively small frequencies and the organic matter did not affect the occurrence very much. In the other group, *Poa annua* sometimes occured with relatively high frequencies and in these crops the organic matter was rather important. Within these groups the crops did not seem to be confounded with any geographical, climatic or edaphic conditions.

Fodder beets and sugar beets differed in Fig. 7, probably because the two crops are grown in different geographical regions with contrasting soil types and land use. Fodder beets are grown more widely in the western part of Denmark, dominated by sandy soils and animal husbandry, whereas beets for sugar production are confined to the Danish isles with clay and loamy soils, where arable farming dominates.

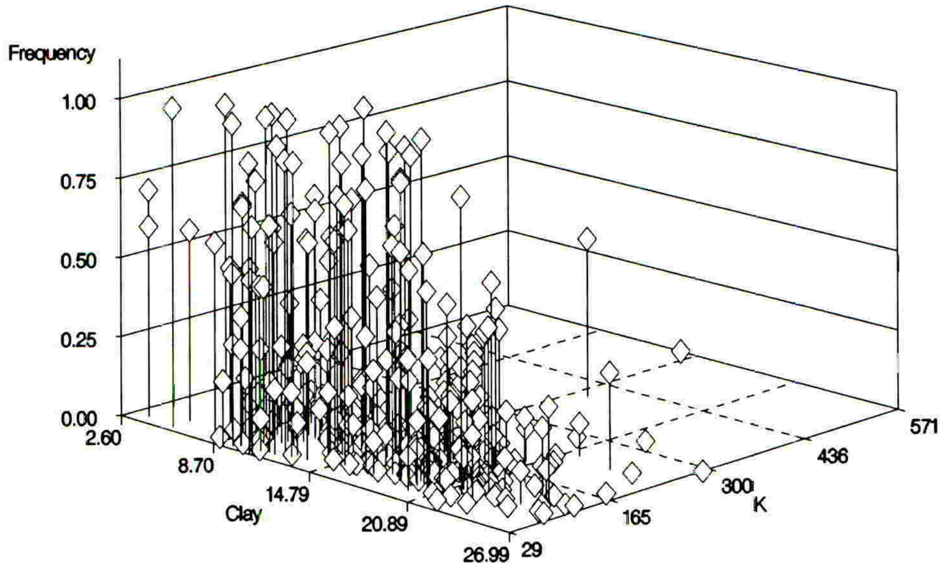

FIGURE 1. Observed frequency of *Viola arvensis* in response to soil clay (%) and potassium (K, unit: mg/kg) contents.

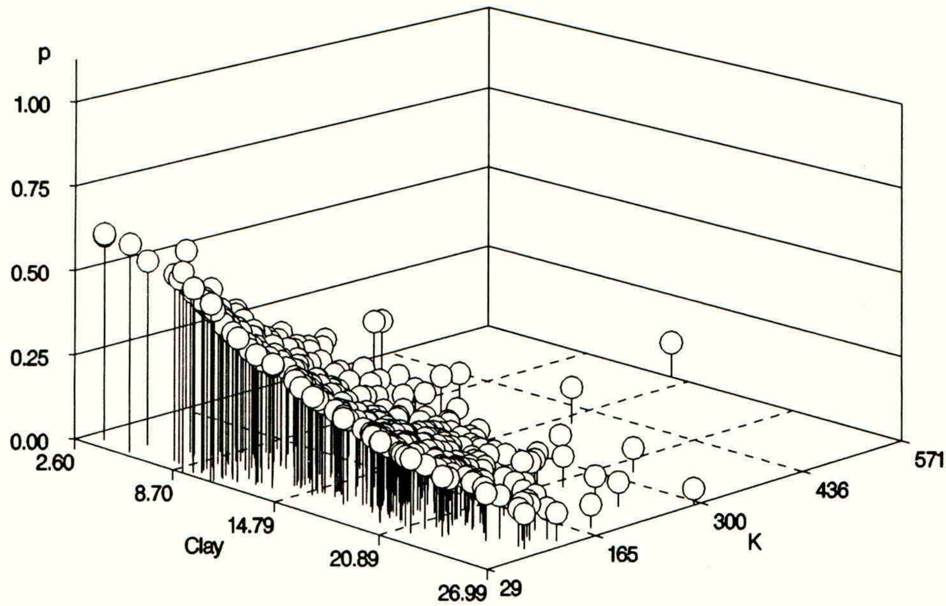

FIGURE 2. Predicted frequency (p) of *Viola arvensis* in response to soil clay (%) and potassium (K, unit: mg/kg) contents (Eq. 3).

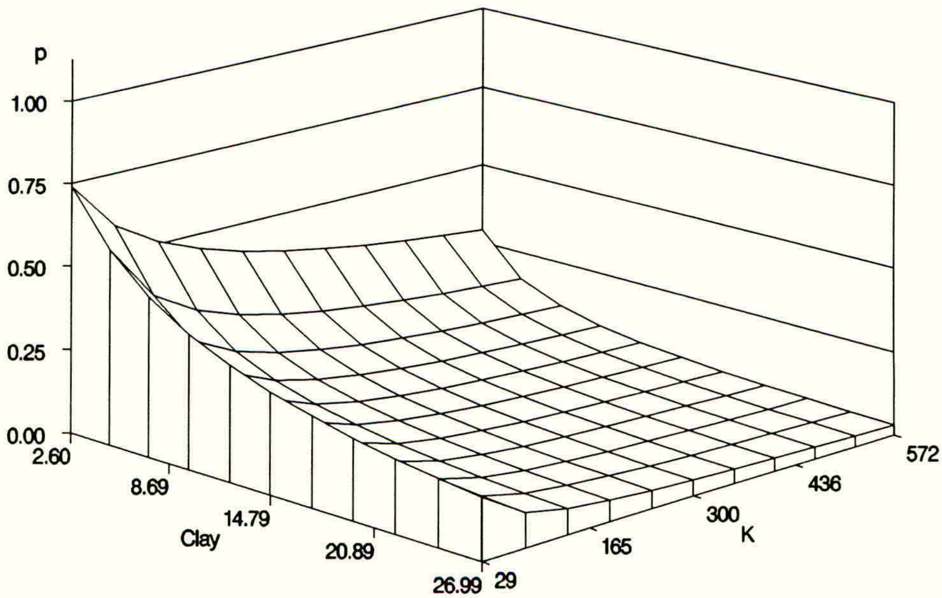

FIGURE 3. Predicted frequency (p) surface for *Viola arvensis* in response to soil clay (%) and potassium (K, unit: mg/kg) contents (Eq. 3).

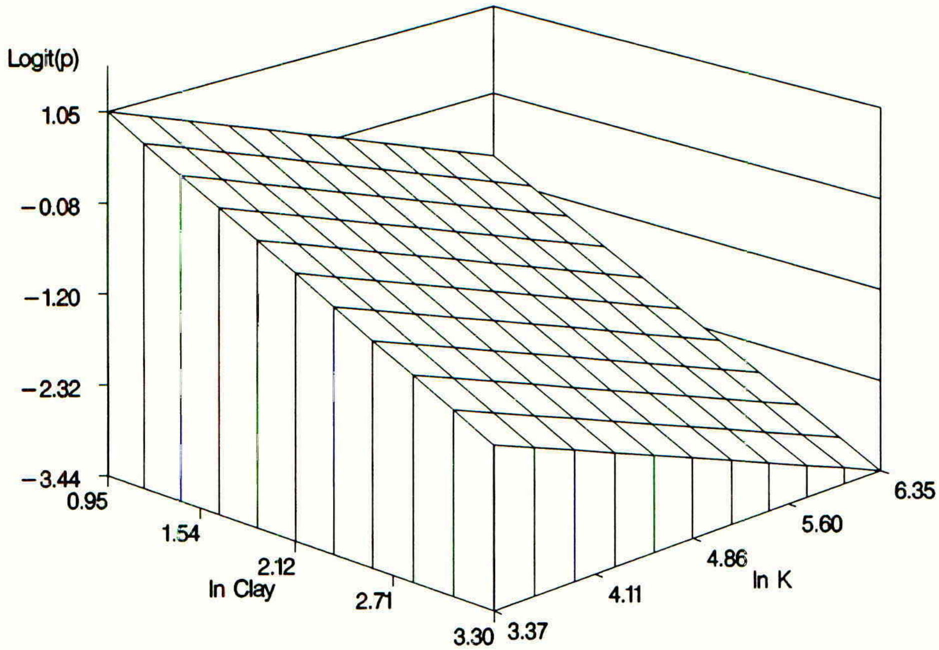

FIGURE 4. Predicted logit response (Logit(p)) surface of *Viola arvensis* in response to the logarithm of soil clay (ln Clay) and potassium (ln K) contents (Eq. 2).

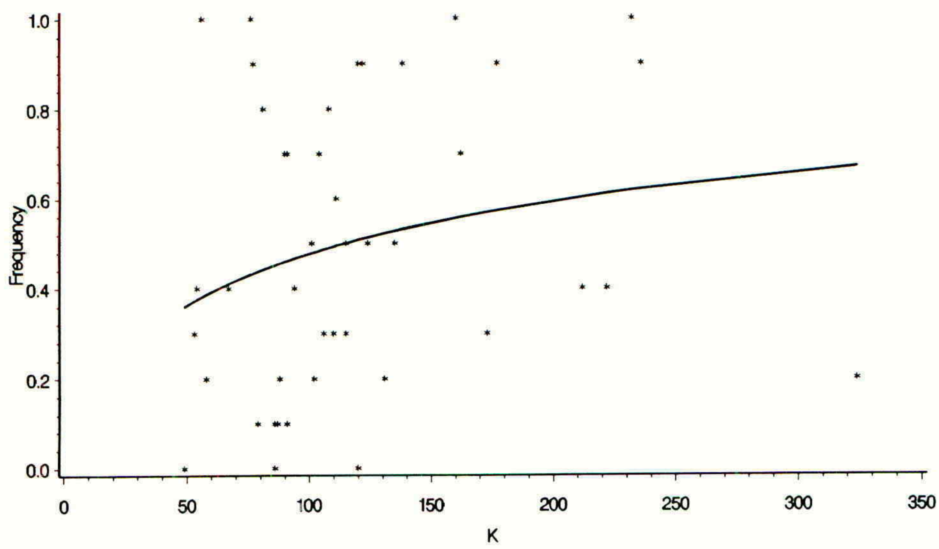

FIGURE 5. Observed (*) and predicted (—) frequencies of *Stellaria media* in response to soil potassium (K, unit: mg/kg) content in spring barley.

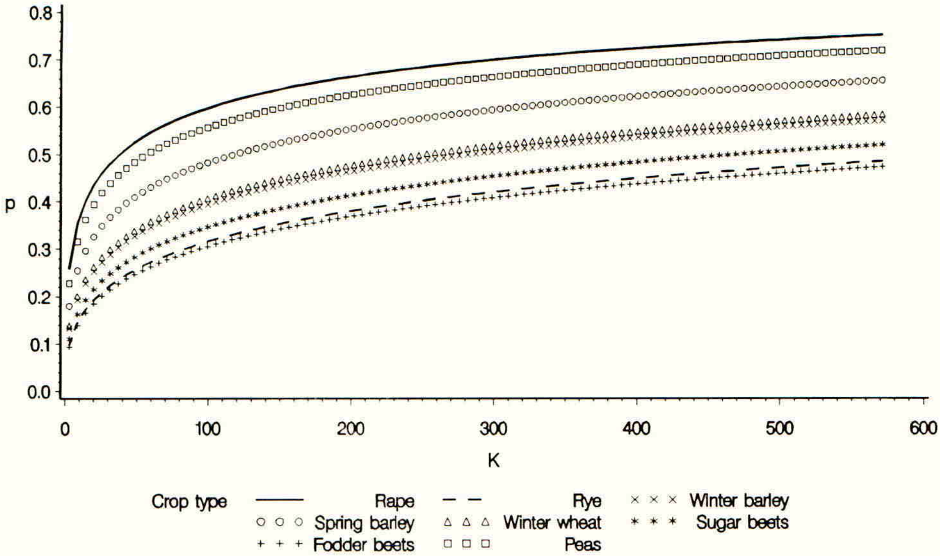

FIGURE 6. Predicted frequency (p) of *Stellaria media* in response to soil potassium content (K, unit: mg/kg) within crops.

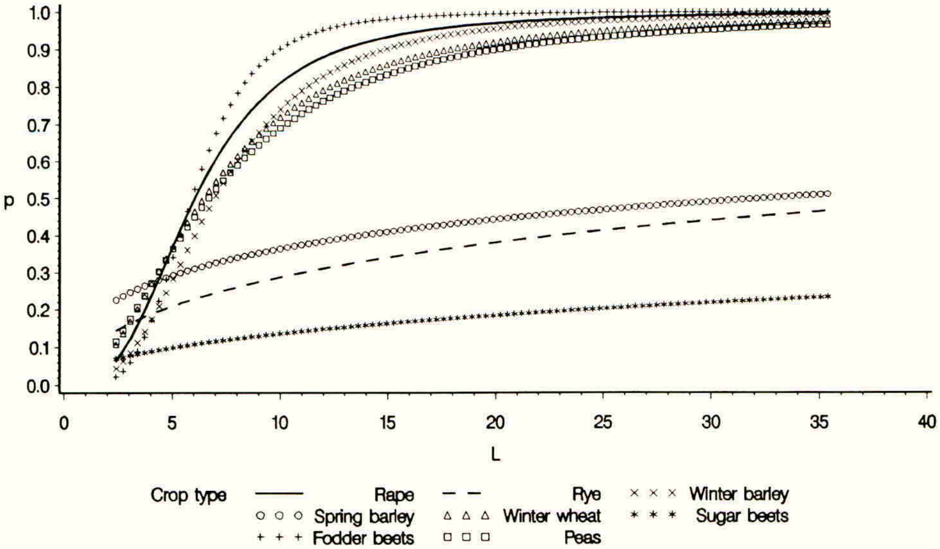

FIGURE 7. Predicted frequency (p) of *Stellaria media* in response to soil potassium content (K, unit: mg/kg) within crops.

In Denmark it was prohibited by the law of 1990 to burn straw on the fields which has resulted in an increased use of straw mulching. This has been reinforced by the statuary legislation of crop rotation, use of farmyard manure and compulsory green cover of fields in winter. This legislation aims at reducing nitrate leaching and ensuring optimal use of farm manure and commercial fertilizers (Anonymous, 1988b). It prescribes from 1990 onwards that generally 65 per cent of arable land on a farm must be covered with green crops during winter. It is permitted to substitute straw mulching on twenty per cent of the arable area of a farm with undersown catch crops. The condition is that 1 hectare of catch crop is replaced with 1.6 hectare of straw mulching. These legislative steps will inevitably result in an increasing amount of organic matter in Danish arable fields in the future, possibly with positive effects on the water holding capacity of the soil and thus increased the occurrence of *Poa annua*. Therefore, it is expected that *Poa annua* will become an increasing weed problem in Danish fields.

ACKNOWLEDGEMENTS

We wish to thank Senior Adviser H. Kristensen from The Danish Agricultural Advisory centre, the many farm advisers all over the country who helped in finding sites and the farmers who kindly allowed us to keep unsprayed areas during the survey period. We also wish to thank The Danish Agricultural and Veterinary Research Council for financial support.

REFERENCES

Andreasen, C.; Streibig, J.C.; & Haas, H. (1991) Soil properties affecting the distribution of 37 weed species in Danish fields. *Weed Research*, **31**, 181-187.

Anonymous (1988a) Bekendtgørelse om husdyrgødning og ensilage m. v.. Ministry of the Environment. *Lovtidende*, nr. 568 af 22/9/1988, Copenhagen.

Anonymous (1988b) *Bekendtgørelse om sædskifte- og gødningsplaner samt grønne marker i jordbruget*. Ministry of Agriculture. Miljøkontoret 1.6.j.nr.87.-523/06-28. Copenhagen.

Anonymous (1990) *Landbrugsstatistik 1989*. Copenhagen: Danmarks Statistik, p. 84

Korsmo, E. (1954) *Ugras i nåtidens jordbruk*. Oslo: Nordisk Landbruks Forlag, pp. 473–474.

Kofoed, A. D. (1978) The Potassium Cycle in Cropping Systems. In: *Potassium Research-Review and trends*. Proceedings of the 11th Congress of the International Potash Institute, 1978. Bern, Switzerland, pp. 435–448.

Raunkiær, C. (1934) *The lifeforms of plants and statistical plant geography*. Oxford: Clarendon Press, pp. 201–282.

Weisberg, S. (1985) *Applied linear regression*. Second edition. New York: John Wiley & Sons, Inc., pp. 196–221.

CHANGES IN WEED POPULATIONS AND SEED BANK THROUGH TWO CYCLES OF A MAIZE-SOYABEAN ROTATION IN ONTARIO, CANADA

D.L. BENOIT

Agriculture Canada, Research Station, 430 boulevard Gouin, Saint-Jean-sur-Richelieu, Québec Canada J3B 3E6

C.J. SWANTON, K. CHANDLER, D.A. DERKSEN

Department of Crop Science, University of Guelph, Guelph, Ontario Canada N1G 2W1

ABSTRACT

A study on the effect of reduced tillage and herbicide input on the evolution of weed populations and their seed banks in a maize-soyabean rotation was established in 1985 in southwestern Ontario, Canada. The tillage systems under investigation were autumn moldboard plough (MP), autumn chisel plough (CP), ridge tillage (RT) and no-till (NT). Each tillage experiment compared the use of high herbicide input, low herbicide input and no herbicide (untreated). More perennial weed species were observed in the weed communities of both CP and NT systems than in the other systems. Weed communities of the CP system were not significantly different from MP regardless of the level of herbicide input used. Ridge tillage demonstrated significant differences in weed community composition from all other systems except low herbicide input in the MP system. Total seed bank size was not affected by herbicide input. The same weed species were found as mature plants and in the seed bank.

INTRODUCTION

Weed management involves both tactical short-term and strategic long-term objectives aimed at preventing an unacceptable population increase (Cussans & Moss, 1982). Rapid changes have taken place lately in farming systems with an increased emphasis on greater use of crop rotations and soil conservation techniques and the reduction of herbicide input to satisfy environmental concerns and ensure economic competitiveness. Control practices are aimed at restricting weed populations to some arbitrary level and, in general, greater emphasis is placed on controlling the active (growing) component of weed populations with less emphasis on controlling the passive components (inactive seeds or other propagules in the soil) (Medd, 1987). However, there is a need for a better understanding of the long-term consequences of weed management strategies on the persistence of weed populations in both the 'active' populations at which control measures are aimed and the 'passive' seed banks which provide a source of propagules for reinfestation.

Many studies have investigated the effect of herbicide input and tillage practices on the efficacy of weed control (Buhler & Daniel, 1988; Buhler & Oplinger, 1990) or tillage practices on seed banks (Forcella & Lindstrom, 1988) but rarely both simultaneously (Dessaint et al., 1990a,b;

Schweizer et al., 1988). In most cases the choice of herbicides used was dictated by the weed population present and by the desire to maximize weed control and yields.

The objective of this study was to monitor changes in the weed population and the seed bank after the prolonged use of low and high input of different herbicides in a maize-soyabean rotation under four tillage systems.

MATERIALS AND METHODS

A study was initiated on a private farm in 1985 at Fingal (42°40'N Lat., 81°20'W Long) in southwestern Ontario, Canada. The field was a Beverly silt loam soil with pH 7.0 and the growing area accumulated on average 2900-3000 CHU [corn (maize) heat units]. The tillage systems under investigation were 1) conventional tillage with an autumn moldboard plough and a spring discing, 2) conservation tillage using an autumn chisel plough and a spring discing, 3) ridge tillage using a 'Buffalo ridge cultivator' in the spring and in mid-july for ridge rebuilding and 4) a no-till system where a modified 'John Deer 7000' no-till drill seeder was used. The same seeder was used in all tillage systems.

The experimental design was a complete randomized block with three replications, where plot size was 6 m x 2 m. Each tillage system was carried out in strips across all replications and was thus considered as separate experiments. In each tillage system, three input levels of herbicides were compared: 1) high input where a broad-leaved weed and grass herbicide was used, 2) low input with only a broad-leaved weed herbicide and 3) an untreated plot.

The herbicide treatments were applied using a bicycle-wheel plot sprayer equipped with SS8002LP sprayer nozzles and calibrated to deliver 225 l/ha of spray solution at a pressure of 180 kPa. For the ridge tilled plots, the herbicides were sprayed in 25 cm bands on the ridge with 8002E nozzles. The herbicides used in maize were atrazine at 1.5 kg AI/ha alone in the low input treatment and tank-mixed with metolachlor (2.64 kg AI/ha) in the high input treatment. In soyabean, linuron at 2.25 kg AI/ha was applied alone in the low input treatment and in combination with metolachlor applied at the same rate as in maize in the high input treatment. Glyphosate + 2,4-D were applied to control perennial weeds.

Crops were seeded on May 30, April 30, May 18 and April 29 in 1986 to 1989, respectively. Soyabean cv.Elgin was seeded at 375,000 seeds/ha in 1986 and 1988 while for corn, cvs. Pioneer 3737 and Northrup King 3624 were seeded at 68,750 seeds/ha in 1987 and at 68,395 seeds/ha in 1989, respectively. Herbicides were applied pre-emergence either immediately after seeding (1987) or a few days afterward (May 31, May 19 and May 2 in 1986, 1988 and 1989 respectively). In the ridge tillage system, a second ridging operation was undertaken at mid-season of each year (July 13, 1986; July 2, 1987; June 16, 1988; July 5, 1989). Soyabeans were harvested on October 16, 1986 and October 5, 1988 and corn was harvested on October 21, 1987 and October 19, 1989.

Weed population evaluation and analysis

Weed populations were evaluated once every year in early to mid-august (August 8, 1986; August 12, 1987; August 10, 1988; August 2, 1989) to identify the weed species which survived the weed control programmes. In 1986 weeds were counted in one randomly placed quadrat (25 cm x 25 cm) in each plot, while in 1987 to 1989 two quadrats were used per plot. A canonical discriminant analysis described by Klecka (1980) was performed on the total density of every species present in all plots over the four year period (1986-1989). Mahalanobis squared distances between cluster centroids are presented in Table 2 and these values were compared to a Chi square table to determine the level of significance (Klecka, 1980). The term 'weed community' used in the discussion, takes into account the density parameter and the different weed species present in each plot.

Seed bank evaluation and analysis

Seed bank populations were monitored over two cycles of the maize-soyabean rotation and the following spring. During the rotation cycles, the seed bank was sampled every year prior to seeding and herbicide application (April 25, 1986; May 6, 1987; May 18, 1988; April 29, 1989; April 24, 1990). A total of 70 soil samples (2.5 cm diameter and 20 cm deep) were collected for each plot, bulked and stored at 4°C. The number of seeds in the soil was evaluated by the germination technique. Soil samples spread out in 3 cm layer in two containers (26 cm x 40 cm), were placed in a growth chamber with a 16h photoperiod and fluctuating day and night temperatures of 20° and 15°C for a period of 6 months. Weed seedlings were identified and counted at emergence and a thorough soil stirring was made once a month. Soil samples were stored for 3 months in a cold room at -4°C in darkness and returned to the growth chamber for an additional 3 months for further germination. The 1986 seed bank data were removed from further analysis because of equipment failure during the germination periods which rendered the estimations unreliable.

Data for the total number of weed seeds m^{-2} were transformed by the $(X+0.5)^{1/2}$ prior to analysis in order to obtain a normal distribution. An analysis of co-variance was performed with 1987 to 1989 data in order to determine the effect of the covariate (ie. the initial seed bank size) on the treatment means of the final seed bank size. Subsequently analyses of variance on the transformed total number of seeds m^{-2} were made using SAS programs. The original values were used to present the results in figure 2.

RESULTS AND DISCUSSION

Comparison of the total number of species between seed banks and field populations

The total number of species present as seeds in the soil and mature plants ranged from 5 to 12 and 5 to 19 respectively. In both cases, the untreated plots had greater number of species present than the treated plots in all tillage systems except in the seed bank of the ridge tillage (Table 1). All no-till treatments had as many weed species present in the field as the untreated plots under other tillage systems. In 1987, the Chenopodium album population escaped control measures and was diagnosed the following year as atrazine-resistant C. album. This species later became a major problem on the site.

The same weed species present as mature plants were also present in the seed bank. However, they contributed to a different extent to the seed bank. Similar observations were made by Dessaint et al. (1990a,b). The appearance of atrazine-resistant C. album in the field was followed by the appearance and increase of the C. album population in the seed bank. In 1989 lamb's-quarters's contribution to the seed bank had reached levels of 47 to 81%, with the highest contribution percentages consistently observed in the no-till system and in the chisel plough system. (Benoit, unpublished data).

Table 1. Total number of weed species present in the soil and in the field within each tillage systems through two cycles of a maize-soyabean rotation.

	Number of species			
	Moldboard	Chisel plough	Ridge plough	No-till tillage
SOIL				
untreated	11	12	8	12
low input	9	7	11	9
high input	5	10	8	9
FIELD				
untreated	11	13	12	19
low input	6	7	8	12
high input	5	6	5	10

Dominant species in the soil: C. album, Ambrosia artemisiifolia, Setaria viridis, Oxalis stricta.
Dominant species in the field: C. album, A. artemisiifolia, S. viridis, Setaria glauca, Abutilon theophrasti.

The type of tillage influenced the appearance of biennial and perennial weeds in the weed population and in the seed bank. The moldboard plough had the least number of perennial species while the no-till system had both biennial (Daucus carota) and perennials (Cyperus esculentus, Solidago canadensis, Physalis heterophylla and Taraxacum officinale) present. The chisel plough system also had several perennial species present.

Weed community composition in the field

Differences in observed weed population dynamics between published reports (Buhler & Oplinger, 1990; Wrucke & Arnold, 1985) strongly suggest that both the initial weed species composition and the overall combination of rotation, tillage, and herbicide input will ultimately influence the final outcome in weed population dynamics. This was demonstrated by the results of this study.

The discriminant analysis indicated that where no herbicides were used (untreated), the composition of the weed community in the no-till treatment was significantly different ($P<0.01$) than all other tillage systems (Table

2). However, when herbicides (low or high input) were used, weed commmunity composition in no-till was not different from moldboard and chisel plough system, but was significantly different (P<0.05) from ridge tillage (Table 2). The weed community of the chisel plough system was not different from moldboard plough regardless of the level of herbicide input. On the other hand, ridge tillage differed significantly (P<0.05) in weed community composition from all other tillage systems except for the low herbicide input in the moldboard plough system (Table 2). Compositional differences in ridge tilled plots may be caused by the use of herbicide banding and inter-row tillage introducing potential habitat differences within the field (Forcella & Lindstrom, 1988). Furthermore, the total weed density in these treatments were lower than no-till and chisel plow treatments (Fig. 1) and few perennial weed species were found in the ridge tillage system. The inter-row cultivation in mid-July corresponds usually to a dry, hot spell during the growing season in Ontario, thereby, reducing the probability of weed germination. Similarly, this inter-row cultivation maintains weed populations at a low level by uprooting weeds in between the rows and burying those that have survived herbicide banding.

Table 2. Mahalanobis squared distances on the upper right of the matrix diagonal and level of significant differences between tillage treatments on the lower left of the matrix diagonal (p<0.1 *, p<0.05 **, p<0.01 ***).

	Moldboard Plough	Chisel Plough	Ridge Tillage	No-till
Untreated - Tillage alone				
Moldboard plough	-	4.48	6.61	13.07
Chisel plough	NS	-	6.76	13.66
Ridge tillage	*	*	-	15.0
No-till	***	***	***	-
Low Input				
Moldboard plough	-	1.87	5.02	4.08
Chisel plough	NS	-	7.34	3.80
Ridge tillage	NS	*	-	8.76
No-till	NS	NS	**	-
High Input				
Moldboard plough	-	0.79	6.35	3.49
Chisel plough	NS	-	6.47	4.42
Ridge tillage	*	*	-	11.14
No-till	NS	NS	**	-

No-till treatments had a greater total weed density in untreated plots than other tillage systems (Fig. 1). Untreated ridge tilled plots had similar total weed density compared to those in the moldboard plough system. However, when herbicides were applied in both moldboard plough and ridge tillage treatments , total weed density differed only in the low herbicide input plots (Fig. 1). Total weed densities in the chisel plough system were intermediate between no-till and moldboard plough system regardless of herbicide input (Fig. 1).

Total seed density in the soil

The analysis of co-variance on the transformed total seed density for every tillage system from 1987 to 1989 demonstrated that for all tillage systems, the variation of the initial total seed bank density (covariate) had no significant effect on the subsequent total seed bank density as influenced by the different herbicide input levels.

For each tillage system, there existed significant differences in the total number of seeds m^{-2} between years but not between herbicide input or for the year by herbicide interaction (data not presented). The highest

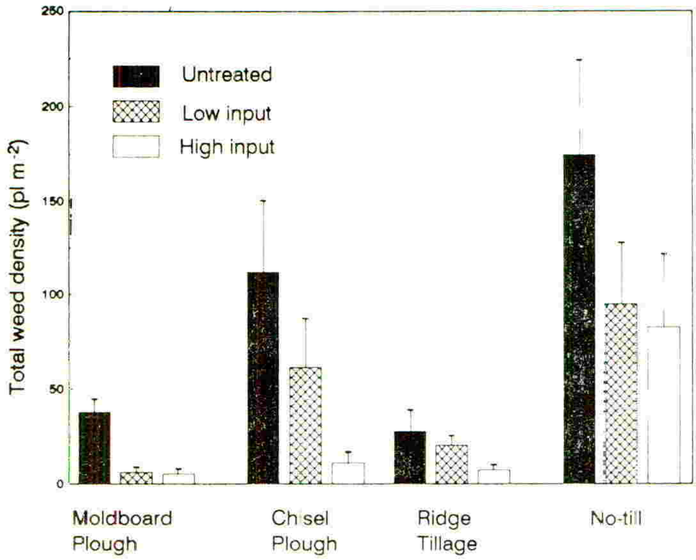

FIGURE 1. Total weed density for three levels of herbicide input under four tillage systems.

total seed densities were present in the no-till system and in the untreated plots of the chisel plough system in 1988. This confirms reports by Dessaint et al. (1990a) where shallow cultivation and plots with no herbicide application had a larger total seed bank than herbicide-treated or deeply cultivated plots. The drastic increase in total seed density in 1988 in all tillage systems corresponded to the large seed rain from the uncontrolled atrazine-resistant C. album in the field. Indeed for no-till, 1988 total seed density was significantly greater ($P<0.05$) than 1987 and 1989 seed densities (Fig.2). For all other systems, total seed density in 1987 was significantly lower ($P<0.05$) than both 1988 and 1989 seed densities (Benoit, unpublished data). The only significant differences in total seed densities for different levels of herbicide input were observed in 1987 in the no-till treatments. Here, the total seed densities in the low input herbicide plot were significantly different to the high herbicide input plot. In 1989 in the moldboard plough system, the untreated plot was significantly different from either inputs of herbicide plots (Fig. 2).

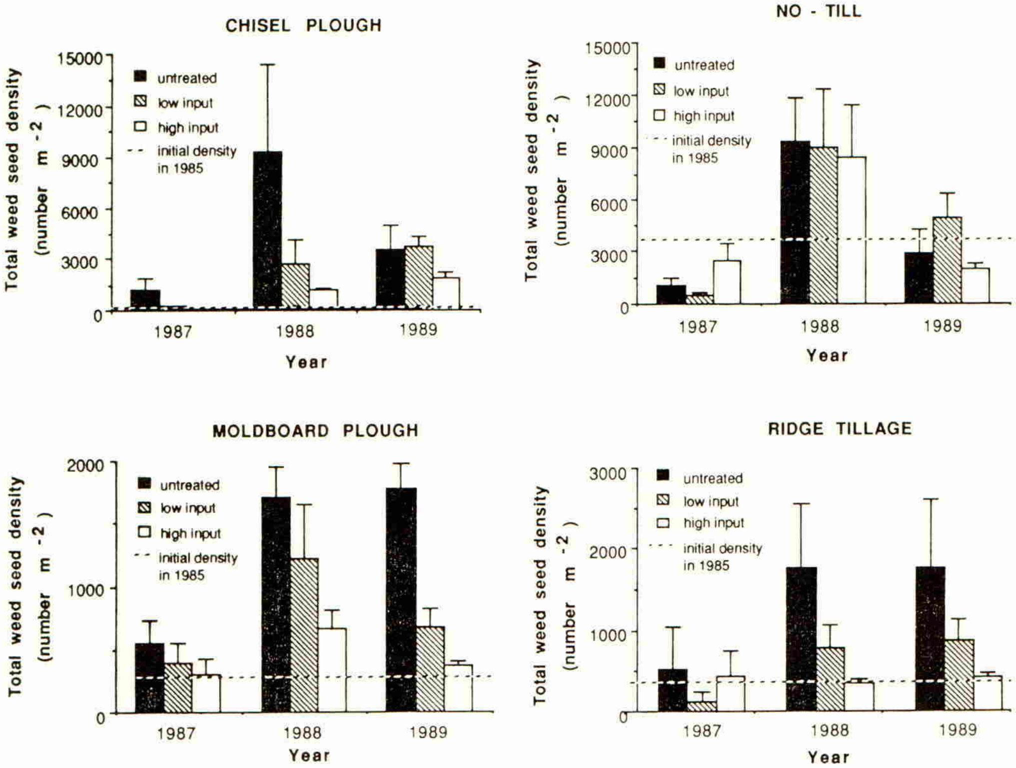

FIGURE 2. Total weed seed density for three levels of herbicide input under four tillage systems from 1987 to 1989. Dotted lines represent the initial seed densities for each tillage system in 1985.

CONCLUSION

Weed management programmes in a maize-soyabean rotation based on the repetitive use of a few herbicides (high or low input) over several years resulted in similar species community response within each tillage system. Total seed bank size was not affected by herbicide input. The no-till system maximized soil conservation but resulted in greater weed populations that required effective control of both annual and perennial weed species. Indeed, the no-till system in a maize-soyabean rotation significantly benefited from increased herbicide input, either in terms of a lower weed species composition and weed densities in the field or by a smaller seed bank. It is the ridge tillage system which represented the best management programme combining weed control efficacy with reduced herbicide input and soil conservation objectives.

ACKNOWLEDGEMENTS

The authors thank Al Jones for participating in the project 'Tillage 2000' and for allowing field work on his farm. D.L. Benoit thanks Gilles Brassard and Manon Bélanger for their technical assistance. The authors express their gratitude to the Technology Evaluation and Development (TED) subprogram of the Soil and Water Environmental Enhancement Program (SWEEP).

REFERENCES

Buhler, D.D.; Daniel, T.C. (1988) Influence of tillage systems on giant foxtail, Setaria faberi, and velvetleaf, Abutilon theophrasti, density and control in corn, Zea mays. Weed Science, 36, 642-647.

Buhler, D.D.; Oplinger, E.S. (1990) Influence of tillage systems on annual weed densities and control in solid-seeded soybean (Glycine max). Weed Science, 38, 158-165.

Cussans, G.W.; Moss, S.R. (1982) Population dynamics of annual grass weeds. In: Decision making in the practice of crop production. R.B. Austin (Ed.), BCPC, London, pp.91-98.

Dessaint, F.; Chadoeuf, R.; Barralis, G. (1990a) Etude de la dynamique d'une communauté adventice: II. Influence à long terme des techniques culturales sur le potentiel semencier. Weed Research, 30, 297-306.

Dessaint, F.; Chadoeuf, R; Barralis, G. (1990b) Etude de la dynamique d'une communauté adventice: III. Influence à long terme des techniques culturales sur la composition spécifique du stock semencier. Weed Research, 30, 319-330.

Forcella, F.; Lindstrom, M.J. (1988) Weed seed populations in ridge and conventional tillage. Weed Science, 36, 500-503.

Klecka, W.R. (1980) Discriminant analysis. Beverly Hills, California; Sage Publications, 70pp.

Medd, R.W. (1987) Weed management on arable lands. In: Tillage. New directions in Australian agriculture. P.S. Cornish and J.E. Pratley (Eds), Melbourne: Inkata Press, pp.222-259.

Schweizer, E.E.; Lybecker, D.W.; Zimdahl, R.L. (1988) Systems approach to weed management in irrigated crops. Weed Science, 36, 840-845.

Wrucke, M.A.; Arnold, W.E. (1985) Weed species distribution as influenced by tillage and herbicides. Weed science, 33, 853-856.

THE EFFECT OF HERBICIDE AND FERTILISER RATE ON WEED PRODUCTIVITY IN SPRING WHEAT.

A.C. GRUNDY, R.J. FROUD-WILLIAMS

Department of Agricultural Botany, School of Plant Sciences, T.O.B.2 Earley Gate, University of Reading, Reading, Berks, RG6 2AU,

N.D. BOATMAN

The Game Conservancy, Fordingbridge, Hants, SP6 1EF.

ABSTRACT

A trial was conducted within a commercial crop of autumn sown spring wheat involving four rates of nitrogen (0,40,80 & 160kgN/ha) with and without the use of herbicide. The weed population was monitored throughout the season for species composition, density, above-ground dry weight and seed production. Total weed dry weight per plot was found to be positively correlated with increasing nitrogen rate up until the final weed harvest. Species dry weights and reproductive output were generally found to be higher on the fertilised plots. The main weed species present were Viola arvensis, Papaver rhoeas, Veronica persica and Veronica arvensis. The use of herbicide suppressed weed seed numbers and dry weight production on all plots, but the response differed between individual species. Reduced input systems would increase the reproductive potential of some species over others and this will have implications for weed seed return, future infestations and management.

INTRODUCTION

Intensive nitrogen fertiliser use may affect weed floras in several ways including increasing the occurrence of competitive nitrophilous species and reducing species diversity. Other possible results of continued intensive nitrogen use were discussed by Chancellor and Froud-Williams (1986). An important result of less intensive cereal farming may be a more diverse weed flora, providing potential host plants within the crop for insects which in turn provide food for gamebird chicks (Sotherton et al, 1985). Increased gamebird populations may be of financial benefit to a farmer who wishes to have organised shoots on his land. This may in turn help to counteract the loss in profit from less intensive cereal production. Weeds also contribute to soil cover, which can help reduce erosion, and they provide an alternative food source for pests as well as offering refuge to beneficial predators.

An experiment was therefore set up in February/March 1990 to investigate the potential effect of reduced fertiliser inputs, on the weed population of an arable field. The objectives were to determine how a reduction in nitrogen rate affected competitive ability of the weed population, species composition, density, above-ground dry weight and reproductive productivity. A herbicide treatment was either applied or omitted to assess the effect of herbicide and interaction with fertiliser rates.

MATERIALS AND METHODS

The experiment was carried out in a 49.7 ha field near Basingstoke, ideal for the purposes of the trial in that it was relatively flat with a reasonably evenly distributed weed flora. The crop, an autumn-sown spring wheat (cv. Tonic) was drilled on 14th November 1989 into a flinty calcareous soil.

Four nitrogen fertiliser rates were applied, with and without herbicide, giving a total of eight treatments which were replicated 6 times. The fertiliser rates were; 0,40,80 and 160kgN/Ha. Plots were 3m by 24m arranged in a randomised block design.

The fertiliser on the 160kgN/ha plots was applied as a split dressing of 2 x 80kg, with the first dressing being applied by hand on the 20 March 1990 and the second on 11 April. The 40 and 80kgN/ha treatments were applied in full on 11 April.

Herbicide was applied to the selected plots on 25 April using a mixture of 0.056kgAI/ha clopyralid, 0.15kgAI/ha fluroxypyr and 0.25kgAI/ha ioxynil with an Oxford Precision Sprayer at a volume rate of 240l/ha.

Monitoring of the weed population was carried out at 3 to 4 week intervals from the beginning of March until the weeds had senesced at the end of July. The final weed harvest was taken on 5 July. The end 3m of each plot was set aside for destructive harvesting of the weeds. On each assessment date an area of $0.1m^2$ was harvested by removing all above-ground weed material. Care was taken to note where harvests were taken so as not to harvest the same area at a later date. Samples were stored in polythene bags in a deep freeze before processing. Samples were separated into species, counted and then dried. Drying was carried out overnight at 80^0C or until there was no further change in dry weight particularly so with the larger samples collected later in the season. The crop was harvested on the 23rd August with a plot combine.

Assessments of seed numbers were based on the final harvest as all species assessed had started to shed seed. Both mature capsules and flowers that were potentially able to produce capsules before plant senescence were counted.

RESULTS

Species diversity

Following commencement of the experiment, a general survey of all plots was taken to assess overall species composition and weed density on the experimental area. A total of 18 weed species were recorded on the experimental site. At harvest diversity on the treatment plots was found not to be significantly altered by nitrogen rate, however the application of herbicide drastically reduced the number of species present (Table 1). Analysis of variance indicated no interaction between nitrogen rate and herbicide usage at the 5% level. The most abundant species were, Viola arvensis(76.5%), Papaver rhoeas, Stellaria media, Veronica persica and Veronica arvensis.

TABLE 1. Mean number of weed species recorded m^{-2} at the final harvest.

Nitrogen rate (kgN/ha)	With Herb	No Herb	Mean
0	0.83	5.83	3.33
40	0.83	6.50	3.67
80	0.83	6.17	3.50
160	0.83	5.17	3.00
Mean	0.83	5.92	

SED Herbicide = 0.317; 35 d.f.

Density

The initial weed density over the experimental area was 442 plants/m^2. By the final weed harvest the density had increased in all nitrogen treatments without herbicide (Table 2). There was a significant reduction in total weed numbers per unit area with increased nitrogen fertiliser at final harvest, the lowest numbers being on the 160kgN/ha plots and the greatest on the unfertilised plots.

The component species differed in their response with the greatest numbers of *Viola arvensis* and *Veronica arvensis* present at low levels of fertiliser. *Veronica persica* had no observed response to nitrogen rate and *Papaver rhoeas* tended towards higher densities on the plots receiving 80kgN/ha.

TABLE 2. Mean number of weeds m^{-2} at the final harvest.

Nitrogen rate(kgN/ha)	With Herb	Without Herb	Mean
0	115	768	442
40	163	692	427
80	100	693	397
160	93	463	278
Mean	118	654	

SED Nitrogen = 61.9; 35 d.f.
SED Herbicide = 43.8; 35 d.f.

Weed dry weight

In general weed dry weight was positively correlated with nitrogen rate throughout the season. However, as harvest approached, the dry weights on the plots receiving the highest rate of nitrogen began to decline whilst the others continued to increase. Total weed dry weight was greatest at 40kgN/ha. (Tables 3a & 3b)

TABLE 3a. Total weed dry weight (g m^{-2}) per $0.1m^2$ at the penultimate weed harvest (13/6/90)

Nitrogen rate(kgN/ha)	With Herb	Without Herb	Mean
0	2.8	21.8	12.3
40	7.8	48.0	27.9
80	3.5	62.2	32.8
160	8.7	67.5	38.1
Mean	5.7	49.9	

SED Nitrogen = 6.71; 35 d.f.
SED Herbicide = 4.74; 35 d.f.

TABLE 3b. Total weed dry weight (g m^{-2}) per $0.1m^2$ at the final weed harvest

Nitrogen rate(kgN/ha)	With Herb	Without Herb	Mean
0	3.4	50.9	27.2
40	6.9	73.5	40.2
80	2.6	75.4	39.0
160	2.9	57.0	29.9
Mean	4.0	64.2	

SED Herbicide = 5.05; 35 d.f.

At the final weed harvest, dry weights of the main component species were assessed for each treatment. In no instance did maximum dry weight occur at the highest level of fertiliser. In the case of Viola arvensis and Veronica arvensis, dry weight per unit area was greatest on the plots receiving 40kgN/ha.

Single plants of the main component species responded differently in terms of their harvested dry weights. The major species in the study, Viola arvensis, responded significantly to the application of nitrogen ($p<0.05$) with maximum dry weights of single plants observed on the 80kgN/ha treatment in the absence of herbicide (Table 3c). Plant dry weights of the other species failed to respond significantly to nitrogen, but dry weights of Papaver rhoeas were greatest on plots with the highest nitrogen rate.

Reproductive output

Potential capsule production in Viola arvensis was found to be significantly greater in the 40kgN/ha treatment ($p<0.05$) than the 0 and 160kgN/ha treatments in the absence of herbicide.

There was an interaction between the application of fertiliser and the effect of herbicide on the production of seed capsules in Viola arvensis ($p<0.01$). Where herbicide had been applied, capsule number was significantly higher on the unfertilised plots or plots receiving only 40kgN/ha (Table 4).

TABLE 3c. Mean dry weight of single plants at final weed harvest (g).

Viola Arvensis

Nitrogen rate(kgN/ha)	With Herb	No Herb	Mean
0	0.0253	0.0548	0.0400
40	0.0312	0.1014	0.0663
80	0.0213	0.1023	0.0618
160	0.0256	0.0907	0.0581
Mean	0.0259	0.0873	

SED Nitrogen = 0.00860; 35 d.f.
SED Herbicide = 0.00608; 35 d.f.
SED Nitrogen x Herbicide = 0.01217; 35 d.f.

Veronica arvensis

Nitrogen rate(kgN/ha)	With Herb	No Herb	Mean
0	0.0000	0.0922	0.0461
40	0.0000	0.0878	0.0439
80	0.0000	0.0621	0.0311
160	0.0000	0.0447	0.0223
Mean	0.0000	0.0717	

SED Herbicide = 0.00963; 35 d.f.

Veronica persica

Nitrogen rate(kgN/ha)	With Herb	No Herb	Mean
0	0.0000	0.0502	0.0251
40	0.0000	0.0559	0.0280
80	0.0000	0.0286	0.0143
160	0.0000	0.0362	0.0181
Mean	0.0000	0.0427	

SED Herbicide = 0.00675; 35 d.f.

Papaver rhoeas

Nitrogen rate(kgN/ha)	With Herb	No Herb	Mean
0	0.000	0.131	0.066
40	0.000	0.114	0.057
80	0.000	0.104	0.052
160	0.000	0.465	0.232
Mean	0.000	0.204	

SED Herbicide = 0.0644; 35 d.f.

TABLE 4. Total potential capsule number per plant for Viola arvensis on final weed harvest.

Nitrogen rate(kgN/ha)	With Herb	Without Herb	Mean
0	0.219	1.398	0.809
40	0.187	2.350	1.269
80	0.073	2.002	1.037
160	0.073	1.903	0.988
Mean	0.138	1.913	

SED Nitrogen = 0.1367; 35 d.f.
SED Herbicide = 0.0966; 35 d.f.
SED Nitrogen x Herbicide = 0.1933; 35 d.f.

In the case of Papaver rhoeas and the two Veronica species, no significant effect of nitrogen rate was observed and herbicide application suppressed the production of reproductive output to negligible levels. However, reproductive structures of these species showed a similar response to that of Viola arvensis, with maximum output, in the absence of herbicide, on the 40kgN/ha treatment .

DISCUSSION

These results indicate that reducing nitrogen inputs, which may form a major strategy under an extensification scheme, could favour higher weed densities within the crop as it approaches harvest. Work by Mahn (1984;1988) demonstrated a similar situation for weed density although the response was observed to continue through the development of the crop.

The reasons for the lower total weed dry weight at 160kgN/ha at the final weed harvest may have been a result of several factors. Firstly, the accelerated weed growth apparent in earlier harvests through the availability of nitrogen, may have resulted in the weeds completing their life cycles earlier and hence senescing before those on the less fertilised treatments. The exceptionally dry climatic conditions during the growing season of 1990 coupled with the weed flora comprising of more early maturing species, may have contributed to the lower dry weights on the highly fertilised plots.

There were, however, no visual signs of senescence in any of the treatments and plant material appeared lush at the final weed harvest, with the exception of the herbicide treated plots. For this reason, the drop in weed numbers at the highest fertiliser level at the final harvest may have been a contributory factor in the reduced overall weed dry weight. The 160kgN/ha plots may have experienced a greater mortality in these final stages when crop competition may have been exaggerated as the crop canopy closed. There is a possibility that at the intermediate reduced nitrogen rates (40-80kgN/ha) the canopy was not complete, enabling weeds to continue growth. This was reflected in above-ground dry weight production per plant, per unit area and also capsule production in Viola arvensis, all of which attained their respective maxima at the intermediate nitrogen levels. Increased weed matter at the intermediate nitrogen levels may cause problems with combining and contamination of the grain.

Potential seed capsule production for Viola arvensis was found to follow the same response to nitrogen rate as single plant dry weight, as discussed earlier. This result would appear to be in agreement with work carried out by Wilson et al. (1988), where individual dry weights of Viola arvensis were shown to be directly related to potential seed production.

It is concluded that reduced nitrogen inputs may increase weed productivity in some species, relative to that at higher nitrogen levels.

ACKNOWLEDGEMENTS

The authors wish to thank the Manydown Farm Company for allowing field work on their estate. A.C. Grundy was funded by an Agriculture and Food Research Council award.

REFERENCES

Chancellor, R.J; Froud-Williams R.J. (1986) Weed problems of the next decade in Britain. Crop Protection, **5**, 66-72.

Mahn, E.G. (1984) The influence of different nitrogen levels on the productivity and structural changes of weed communities in agro-ecosystems. Proceedings 7th International Symposium on Weed Biology, Ecology and Systematics (Paris), 421-428.

Mahn, E.G. (1988) Changes in the structure of weed communities affected by agro-chemicals - what role does nitrogen play? Ecological Bulletins, **39**, 71-73.

Sotherton, N.W; Rands, M.R.W; Moreby, S.J. (1985) Comparison of herbicide treated and untreated headlands for the survival of game and wildlife. Proceedings 1985 British Crop Protection Conference - Weeds, 991-998

Wilson B.J.; Peters N.C.B.; Wright K.J.; Atkins H.A. (1988) The influence of crop competition on the seed production of Lamium purpureum, Viola arvensis and Papaver rhoeas in winter wheat. Aspects of Applied Biology, **15**, 289-296.

CHANGES IN THE VEGETATION AND INVERTEBRATE COMMUNITIES OF SET-ASIDE ARABLE LAND.

N.E. JONES, P.J. KENNEDY, R.E.L. NAYLOR, M.R. YOUNG, D. ATKINSON.

Departments of Agriculture and Zoology, University of Aberdeen, AB9 1UD, Scotland, UK.

ABSTRACT

Plant and invertebrate populations were studied on set-aside (ex-arable) land adjacent to semi-natural areas (woodland, bog and river-bank) within intensively managed farmland. Preliminary analysis of the data shows that two years from inception there have been some small, but detectable, changes in the composition of populations on the set-aside. The species composition of the vegetation on set-aside, which initially reflected the arable weed flora, has been augmented by some invasive, aggressive species. Similarly, the invertebrate population was characterised by mobile, invasive species.

INTRODUCTION

Public pressure and the economic implications of EC grain surpluses resulted in the introduction in October 1988 of the set-aside scheme. The aim of this is to reduce the area of land under cultivation. To enter this voluntary scheme, a farmer must take out of any form of agricultural production at least 20% of arable land. Most set-aside areas are managed as fallow land, the vegetation left to develop by natural regeneration after the last harvest, although grass mixtures may be sown. Vegetation must be cut at least once a year. In addition to reduced crop production, set-aside is portrayed as a mechanism to promote wildlife conservation and to enhance and conserve the environment (Anon, 1988).

The Joint Agriculture and Environment Programme (JAEP) is a research initiative of AFRC, ESRC and NERC, three of the UK Research Councils. The spatial dynamics of plant and animal populations in both arable and semi-natural habitats within farmland and the movement between habitats is a major programme topic. The project at Aberdeen is an integrated programme involving studies on vegetation, invertebrates and small mammals. It aims to assess the importance of set-aside fallow land as a habitat into which species, which may be of conservation value, may disperse from adjacent semi-natural habitats. The dispersal of species between semi-natural, set-aside and arable areas has implications for siting of set-aside areas to maximise wildlife and conservation benefits.

This report is a preliminary analysis of changes in the vegetation and populations of some ground surface invertebrates (spiders (Araneae) and ground beetles (Carabidae)) on set-aside. The aim is to assess the contribution of species from adjacent semi-natural areas after two full seasons without soil disturbance and cropping. The results of parallel studies on small mammals are not presented.

METHODS

Study site

Field work was carried out at Aberdeen University's Aldroughty Farm near Elgin, Morayshire in North East Scotland, where there are a number of areas of semi-natural vegetation adjacent to arable fields. It is a mixed arable/livestock farm of 94 ha and the fields concerned in the study have a history of intensive crop management, mainly of spring barley, with occasional carrot and potato crops. The soil type is generally loamy sand or sandy loam. The rainfall is 650 mm $year^{-1}$.

After harvest of cereal a number of areas were set-aside and left to regenerate naturally. Vegetation and invertebrate studies concentrated on three areas, the results from two of which (Fields A and B) are presented in this paper.

In Field A, a slightly sloping headland area of 0.44 ha was set-aside in October 1988, to form a corridor approximately 110 m long and 40 m wide, between a wood and a bog and bounded by a stone wall. The wood is dominated by *Fagus sylvatica* and *Acer pseudoplatanus* with isolated *Pinus sylvestris* and a sparse field layer. The bog vegetation is predominantly *Ranunculus repens*, *Filipendula ulmaria*, *Juncus* spp. and *Rumex* spp. These semi-natural areas are separated from the field by a track and a ditch respectively, forming possible barriers to the dispersal of the flora and fauna.

In Field B a series of 8 plots each 15 m x 40 m were set up in October 1989 running lengthwise along the field boundary beside the bank of the River Lossie. Using a randomised block design, four plots were set-aside and four continued under intensive arable management. The river bank has a more varied flora than either of the semi-natural areas associated with Field A, including trees,(mainly *Salix* spp and *Sambucus nigra*), shrubs (*Ulex europaeus*, *Sarothamnus scoparius* and *Rubus* spp.) and a variety of forbs (notably *Aegopodium podagraria*, *Chamerion angustifolium*, *Holcus lanatus* and *Anthriscus sylvestris*).

Vegetation sampling

Eleven permanent quadrats were established 10 m apart in each of two parallel transects, one through the set-aside and one through the arable area of Field A. In addition, each semi-natural area and the top and bottom 20 m of set-aside in Field A adjacent to the two semi-natural areas were monitored by 25 randomly positioned quadrats. Each plot in Field B was assessed using 10 random quadrats. The species present in quadrats of 1 x 1 m were identified (Clapham, Tutin & Warburg, 1981) and their percentage cover estimated. Data were collected five times a year at 8 week intervals from March to November, starting in May 1990. This paper presents preliminary analyses of data from July 1990 and March and July 1991.

Invertebrate sampling

Invertebrates were sampled on three occasions, between February and July 1990, using pitfall traps (Southwood, 1978) arranged in a regular grid, covering the semi-natural, set-aside and arable areas, in each of Fields A and B (6 x 10 traps and 3 x 40 traps, respectively). The pitfall traps, consisting of plastic cups of 6 cm diameter, were operated on each sampling occasion with 1% formalin killing fluid for four days. Thereafter the trap catches were taken to the laboratory for identification. Araneae and Carabidae were identified to species following the nomenclature of Merrett, Locket & Millidge (1985) and Kloet & Hincks (1977), respectively.

Statistical analysis

The data consist of sample by species matrices of estimated percentage cover of vegetation, and abundance of invertebrate species. This was ordinated by detrended correspondence analysis (DCA) using the FORTRAN program DECORANA (Hill, 1979; Hill & Gauch, 1980). DCA, an improved version of reciprocal averaging (Hill, 1973), enables the reduction of multi-dimensional biological data (typically dozens to hundreds of species or samples) to a few dimensions (typically one to four) each of which represents a complex environmental gradient (Hill & Gauch, 1980). The data can then be plotted as scatter diagrams using the derived axes. Distances between sites on DCA plots are a measure of between-site variability in species composition: sites plotted close together being more similar than sites plotted further apart.

RESULTS

In the DCA analyses the first two axes together accounted for more than 60% of variation in each data-set and thus are the only axes considered here.

Vegetation

Analysis of the species cover data for the second and third years of set-aside in Field A (Fig. 1) clearly shows that there was a major difference between the species compositions of samples from the wood and samples from all other sites. Only on very rare occasions were species which were present in the wood, found in set-aside areas. Although there was some separation of samples from the bog, set-aside and arable areas along axis 1, the scatter plot suggested that differences in species composition between these areas were relatively small. Re-analysis of the data after exclusion of the wood samples revealed a clear separation of bog samples from samples taken from set-aside and arable areas (Fig. 2). Although these areas had species in common (e.g. Holcus lanatus, Ranunculus repens, Rumex spp., Cirsium arvense), there is an obvious difference in overall species composition. Samples from arable sites (crop species were excluded from the analysis) were indistinguishable from samples taken in set-aside areas, but contained on average only 2 to 3 species and had low percentage cover levels (typically 1 to 5%). Within the set-aside area, there was a discernible distinction between sites located in a 20 m strip adjacent to the wood (top) and sites in a 20 m strip adjacent to the bog (bottom). Samples from the top were dominated by annual weed species typical of arable land (e.g. Poa annua, Myosotis arvensis, Sonchus asper, Cerastium fontanum), whereas samples from the bottom were dominated by perennial grass species (notably Agrostis stolonifera, Poa trivialis, Alopecurus geniculatus, and Glyceria sp.). Over the whole set-aside area, however, Holcus lanatus was common and there were many patches of Trifolium repens.

In Field B, samples from the semi-natural area, the river bank, were distinct in species composition from set-aside and arable samples (Fig. 3). There was greater variability in the species composition of samples from the river bank. There is some indication, based on the ordination of set-aside samples from July 1990 and July 1991, that the set-aside areas were becoming more similar to semi-natural areas between the first and second years of set-aside in Field B. During this period, there was a change in the species composition of the vegetation (especially in two out of the four set-aside plots) from annual arable weed species like *Spergula arvensis*, *Poa annua* and *Matricaria matricarioides*, to a flora dominated by *Holcus lanatus* and *Senecio jacobaea*.

Invertebrates

A total of 42 species of Araneae and 26 species of Carabidae were caught in 60 pitfall traps set in Field A in February, March and July 1990, while 27 species of Araneae and 16 species of Carabidae were caught in 120 traps set in Field B in March 1990.

In Field A, the species composition of invertebrate samples from semi-natural areas were clearly different from those caught in both set-aside and arable areas, as demonstrated by the scatter plot of the DCA sample ordination scores (Fig. 4). In contrast, samples from set-aside and arable areas were almost indistinguishable. The species compositions of samples within set-aside and within arable areas were relatively uniform, while the species compositions of samples within the wood and, to a lesser degree, within the bog were relatively diverse.

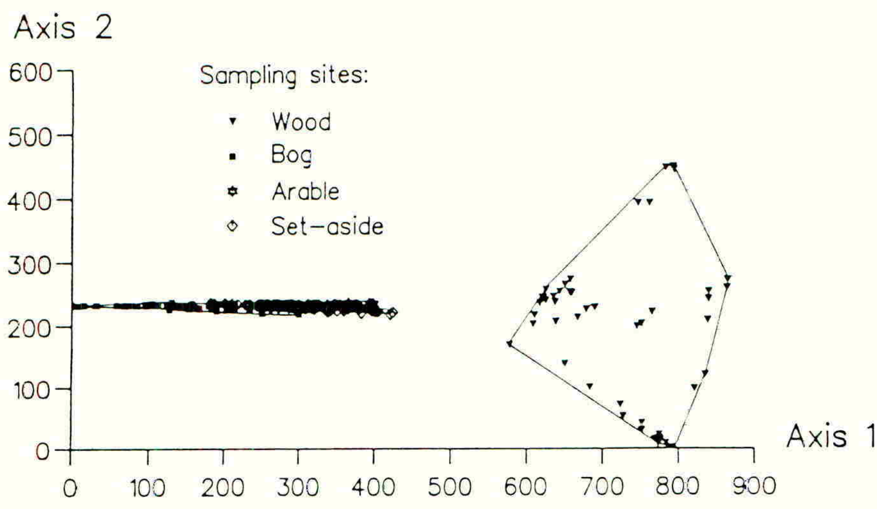

FIGURE 1. Axis 1 by axis 2 scatter plot of DCA ordination of vegetation data in and around Field A.

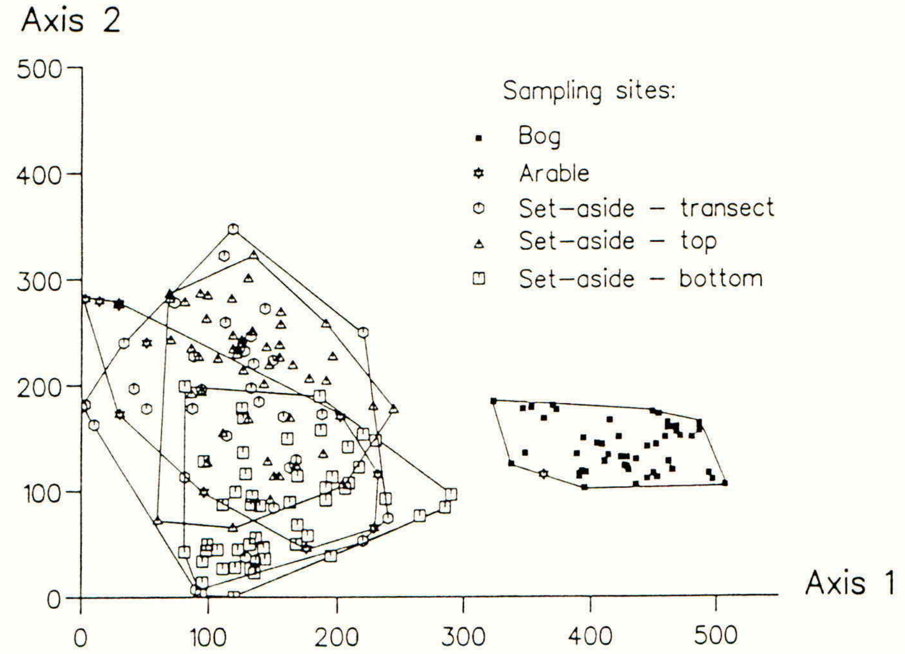

FIGURE 2. Axis 1 by axis 2 scatter plot of DCA ordination of vegetation data in and around Field A, excluding samples from the wood.

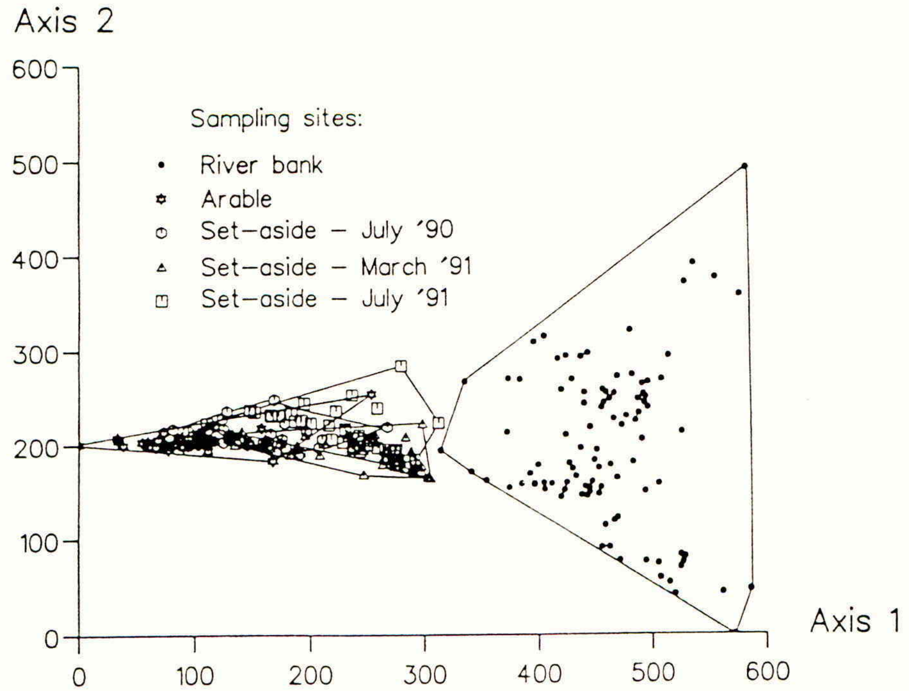

FIGURE 3. Axis 1 by axis 2 scatter plot of DCA ordination of vegetation data in and around Field B.

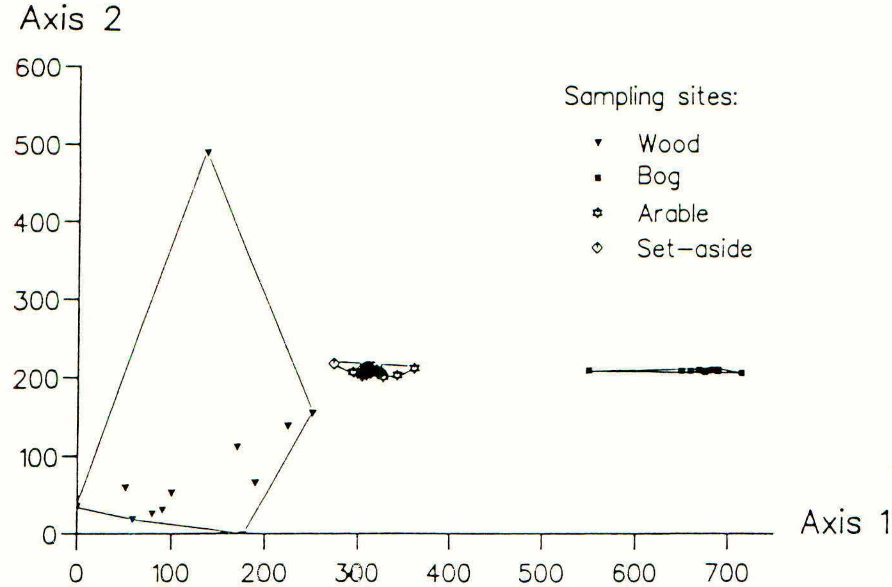

FIGURE 4. Axis 1 by axis 2 scatter plot of DCA ordination of invertebrate data in and around Field A.

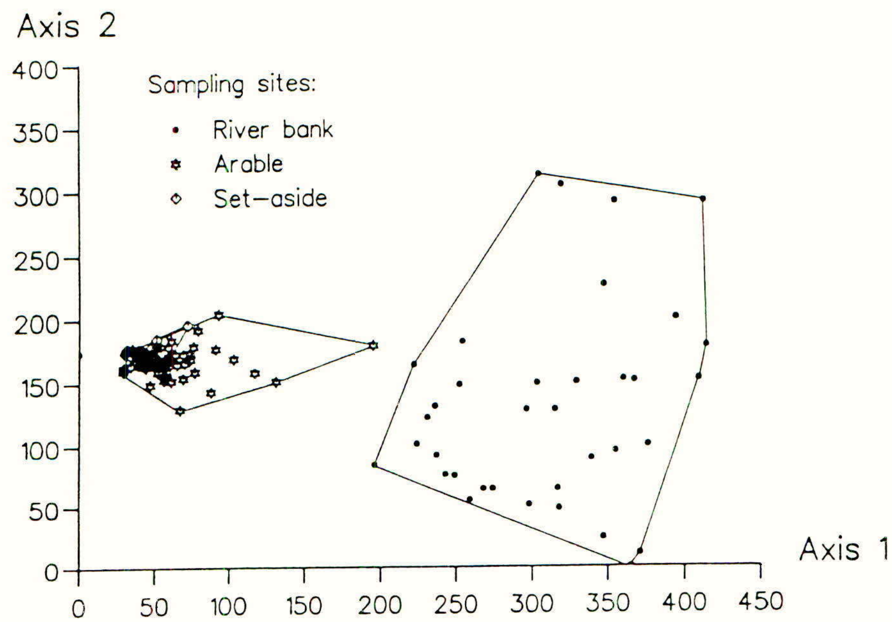

FIGURE 5. Axis 1 by axis 2 scatter plot of DCA ordination of invertebrate data in and around Field B.

The money spiders (Linyphiidae), Erigone atra, E. dentipalpis and Milleriana inerrans, and the carabid, Nebria brevicollis, dominated the pitfall trap catches in set-aside and arable areas, occuring in over 50% of the traps located in these areas. Dicymbium nigrum (Linyphiidae) was the most frequently caught species in traps from the bog, while Microneta viaria (Linyphiidae) and Nebria brevicollis were caught in most traps set in the wood. The occurrence of the latter species in the wood, set-aside and arable areas, and its absence in the bog, probably explains the closer association of set-aside and arable samples to samples from the wood than those from the bog.

For Field B, the separation of semi-natural samples from set-aside and arable samples, and the relative similarity of set-aside and arable samples, was again apparent (Fig. 5). Samples from set-aside and arable areas were again dominated by Erigone atra, E. dentipalpis and Nebria brevicolis. Milleriana inerrans was common in set-aside traps (65%) but only occurred in 17% of traps set in arable areas. These species were less common in traps set along the river bank, in which Dicymbium nigrum and Diplocephalus latifrons (Linyphiidae) were the most widely distributed species.

DISCUSSION

The use of percentage cover as a measure of vegetation composition has the advantage of the speed of estimation. However, there are recognised limitations related to the subjective estimation employed. Large or distinctive species may be overestimated. Cover of grasses is particularly difficult to estimate where there is a mixture of spreading or rhizomatous species and when not all species are in flower. Similarly, although pitfall traps have been used extensively for studies on cursorial, epigeal invertebrates, their use in community studies has been criticised because the catch reflects activity as much as population density. However, both techniques are convenient and well-established. Summarising large, multivariate data sets, while well established in statistical terms, still leaves the problem of interpretation.

The changes in composition of flora and fauna of set-aside demonstrates the short-term response to removal from intensive agricultural management. The species composition of the vegetation would be expected initially to resemble the weed flora of arable land due to regeneration from the seed bank (Roberts, 1970; Harper, 1977; Grime, 1979). Later successional changes occur, either as a result of further seed germination from a persistent seed bank, seed dispersal from other areas, or by the vegetative spread of perennials from immediately adjacent areas. In a study of the first year of set-aside in Field A at Aldroughty, Adams (1989) recorded almost exclusively annual weeds of arable land. This study has shown the decreasing importance of annual arable weed species after the first year of set-aside and the colonisation by aggressive, invasive and perennial species. There was some invasion of the set-aside by species from semi-natural areas (Acer pseudoplatanus, Filipendula ulmaria and Juncus spp.) but it remained dominated by aggressive, invasive species such as Holcus lanatus and Senecio jacobaea. Because the cutting regulations for set-aside effectively prevent the establishment of woody perennials, such as gorse and sycamore, succession to scrub or woodland seems unlikely.

Similarly, the invertebrate species which dominated the catches from arable and set-aside areas are known as ubiquitous, highly mobile and invasive species, and are often pioneer colonisers of new habitats, such as arable fields (Rushton, Topping & Eyre, 1987; Rushton, Luff & Eyre, 1989). In contrast those invertebrate species recorded most frequently in semi-natural areas are characteristic of habitats with a well-developed understorey and litter layer, and are only moderately tolerant of disturbance. In time less mobile and invasive species are expected to play an increased role in the set-aside areas.

ACKNOWLEDGEMENTS

NEJ and PJK are funded by NERC through the JAEP programme.

REFERENCES

Adams, S.J. (Unpublished). A study of the seed bank and vegetation of an arable farm in north-east Scotland. University of Aberdeen: M.Sc. thesis.

Anon. (1988). Guidance on set-aside. Edinburgh: Department of Agriculture and Fisheries for Scotland.

Clapham, A.R., Tutin, T.G. & Warburg, E.F. (1981). Excursion Flora of the British Isles (3rd edition). Cambridge: Cambridge University Press, 499 pp.

Grime, J.P. (1979). Plant strategies and vegetation processes. Chichester: John Wiley & Sons, 222 pp.

Harper, J.L. (1977). Population biology of plants. London: Academic Press, 892 pp.

Hill, M.O. (1973). Reciprocal averaging: an eigenvector method of ordination. Journal of Ecology, **61**, 237-249.

Hill, M.O. (1979). Decorana - A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ithaca, New York, USA: Ecology and Systematics, Cornell University.

Hill, M.O. & Gauch, H.G. (1980). Detrended correspondence analysis: an improved ordination technique. Vegetatio, **42**, 47-58.

Kloet, G.S. & Hincks, W.D. (1977). A checklist of British Insects (2nd edition). Handbooks for the identification of British insects XI, Part 3. London: Royal Entomological Society of London.

Merrett, P., Locket, G.H., & Millidge, A.F. (1985). A check list of British spiders. Bulletin of the British Arachnological Society, **6**, 381-403.

Roberts, H.A. (1970). Viable weed seeds in cultivated soils. Report, National Vegetable Research Station, 1969, 25-38.

Rushton, S.P., Topping, C.J. & Eyre, M.D. (1987). The habitat preferences of grassland spiders as identified using detrended correspondence analysis (DECORANA). Bulletin of the British Arachnological Society, **7**, 165-170.

Rushton, S.P., Luff, M.L. & Eyre, M.D. (1989). Effects of pasture improvement and management on the ground beetle and spider communities of upland grassland. Journal of Applied Ecology, **26**, 489-503.

Southwood, T.R.E. (1978). Ecological Methods (2nd Edition). London: Chapman & Hall, 524 pp.