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# Arable plant communities as indicators of farming practice

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ABSTRACT

The diversity and abundance of the within-field seedbank and emerged weed flora, were measured in over 100 fields from conventional, integrated and organic farms across the arable east of Scotland. Both seedbank and emerged flora showed significant responses to a management intensity gradient from farms with high agrochemical inputs and winter cropping to those with no inorganic inputs, spring cropping and mixed farming practices. The emerged weed flora was more affected by recent agrochemical inputs than was the seedbank, which is buffered by the persistence of weed seeds in the soil. The seedbank was more strongly influenced by soil characteristics, such as % organic carbon and % total nitrogen, than by management. Overall farming approach (categorised here as organic, integrated and conventional) appeared to exert a selection pressure on the species composition of the seedbank, building up different communities under the three farming approaches over time. These effects were scale dependent. At a within-field scale, species richness was greatest in organic farms where there was a greater abundance of weeds. At a regional and landscape scale, species richness was greater in integrated and conventional farms. This was particularly evident in integrated farms which represented a greater range of crop types and cropping practices between fields than either conventional of organic farms alone. Increasing the diversity of cropping practices between fields may offer a complementary approach to reducing agrochemical inputs for enhancing arable biodiversity across landscapes.



## 1. Introduction

Since the early 20th century, the diversity and abundance of the arable weed flora across Europe has declined due to the intensification of crop production systems (Gibson et al., 2006). This reduction in arable biodiversity has been attributed to the increased use of herbicide and the competitive suppression of weeds by autumn-sown crops (Robinson and Sutherland, 2002; Marshall et al., 2003). The most common arable weeds listed by Brenchley (1918) have remained due to their ruderal characteristics and persistence in arable seedbanks, but many of the rarer arable weeds have been severely reduced, even to extinction in some parts of the UK (e.g. Preston et al., 2002).

These arable weeds, including many of the rare species, are increasingly seen as an important source of biological diversity, and crucial to the functioning of arable systems (Norris and Kogan, 2000). They provide a greater variety of form, composition and function than the few crop species that dominate arable land (Hawes et al., 2003). The severe depletion of arable weeds therefore has important implications for the diverse array of associated herbivores, predators and parasitoids that depend on them for food and shelter and which in turn mediate essential biogeochemical processes through the functioning of arable foodwebs (Siemann et al., 1998; Marshall et al., 2003; Hawes et al., 2003, 2009; Taylor et al., 2006).

Nevertheless, the presence of high weed densities in arable fields can cause significant loss of crop yield and quality (Christensen, 1993). The conflicting needs for both food production and arable biodiversity therefore have to be reconciled. Approaches to this can be grouped into three broad categories: conventional farming practices tend to maximise crop yield at the expense of biodiversity by attempting to eliminate the weed burden within fields and utilising as much of the field area as possible; organic approaches are more tolerant of an abundance of within-field weeds, allowing coexistence between the crop and weed flora despite the potential yield loss; integrated farming approaches tend to segregate crop production from biodiversity by reducing weed abundance in cropped areas and managing for biodiversity in the field margins.

To date, the arable seedbank and emerged flora have been used as effective indicators of farmland biodiversity, describing differences among organic, conventional and (occasionally) integrated farms (Bengtsson et al., 2005; Fuller et al., 2005; Gibson et al., 2007; Hole et al., 2005; Tamis and van den Brink, 1999) or the effects of

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specific forms of weed management (Hawes et al., 2003; Heard et al., 2003; Squire et al., 2003). Further studies have dealt with the association between weed density and crop yields (Cousens, 1985; Christensen, 1993). However, the role of management intensity and other field characteristics (e.g. field size and soil type) in creating the differences in weed diversity between farming approaches, and the association between the resulting weed density and crop yields, have not to the authors knowledge been adequately demonstrated at the field scale over large geographic regions.

Here, we investigate the management practices, soil properties and estimated crop yields associated with differences in arable plant diversity across conventional, integrated and organic farms in the arable east of Scotland. The abundance and diversity of the emerged weed flora and seedbank communities were examined in more than 100 commercial fields covering a broad range of management and soil conditions. The aims of the work were to define (a) the management factors that most clearly differentiate farms, and particularly whether they distinguish different farming approach (e.g. organic, integrated, conventional), (b) the extent to which the seedbank and weed flora differ in relation to these management factors as opposed to soil and other characteristics of the field, (c) the degree to which weed density is related to estimated crop yields across different farming approaches, and (d) the response of the weed community to farming approach across spatial scales from the field to the regional and landscape levels.

## 2. Methods

### 2.1. Field sites

The arable weed flora, field management and soil characteristics were assessed in 56 farms across the arable east of Scotland (Fig. 1). Twenty-two farms were located in Aberdeenshire and Invernesshire (north), nineteen in Tayside and Fife (mid), and sixteen in the Lothian and Borders region (south). Twelve farms were certified as organic by the Soil Association and had been under organic cultivation for more than 5 years. Twenty-eight farms were labelled as "conventional farms" whose primary management goal was to maximise yield of the main commodity crops and which did not follow formal integrated management or organic farming approaches. The remaining sixteen farms were members of the LEAF (Linking Environment and Arable Farming) organisation and followed Integrated Farm Management practices (Morris and Winter, 1999). These integrated farms adopted a wide range of different land management approaches, overlapping with both 'conventional' and 'organic' practices. At each farm, two paired fields were selected as representative of different stages in the crop rotation typical for that farm (generally a broadleaf break crop and a cereal crop).

### 2.2. Field management information and classification

Farmers were asked to provide detailed records of the main field operations for the 2007 growing season. This information included crop variety, sowing date and seed rate, soil cultivations (sub-soil, plough, harrow, direct drill), fertiliser inputs (product, composition and date of application), herbicide and pesticide inputs (product, number of active ingredients and date of application), harvest and post-harvest operations (combining, baling, carting, etc.). Farmers were also asked to provide yield estimates for crops harvested in 2007 and a list of crops grown in each field between 2002 and 2006. This cropping history did not include records of herbicide, pesticide or other inputs in previous years because historical data was less complete, and even if available, would generate too many permutations relative to the sample size to be included in a multivariate analysis. A Principal Components Analysis (PCA, Genstat 12th edition) was used to condense all of these variables into a few primary indicators of farm type and management intensity for use in subsequent analyses of weed communities. Generalised linear regressions were used to determine the level of association between each management variable and the first three Principal Component scores. Finally, a general analysis of variance was used to test for differences between the three farm types in (a) the scores on the first three principal components and (b) the variables shown to have significant associations with each of these components.

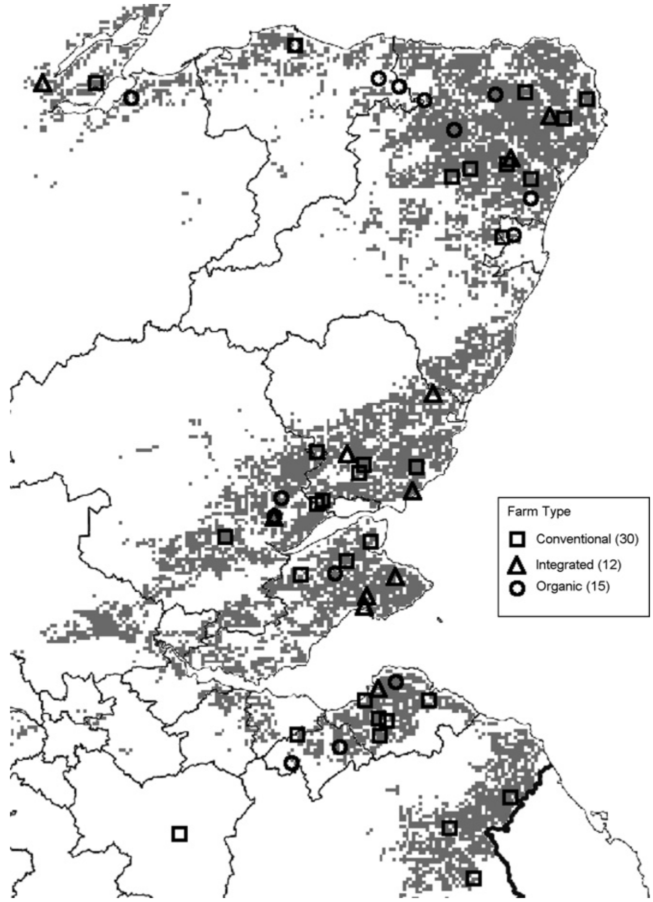


**Fig. 1.** Distribution of conventional (squares), integrated (triangles) and organic (circles) farms surveyed. The shaded area indicates the main arable cropping region in Scotland.

### 2.3. Field sampling

Weed assessments were conducted in May 2007 within a 3-week period, after post-emergence weed treatments (mechanical or chemical) had been applied. Eighty percent of the non-organic fields surveyed received post-emergence herbicide applications. One field had an unusually late application after the weed assessment was conducted. One of the organic fields received post-emergence mechanical weed control prior to the weed assessment and none were reported to have been weeded after May. These few exceptions were typical management practice for the farms surveyed and the data gathered were still representative of the different farming approaches at the time of sampling. The data provide a snapshot of the above-ground weed diversity after any weed treatment had taken effect and while the weeds were potentially competing with the crop. There were no significant differences in rainfall or temperature between 2007 and the 20-year average for the period April to September (data not shown), suggesting that