Significant factors in effective weed control strategies for UK organic arable crops

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Introduction

Farmers, with good reason, have often regarded weeds as the enemy as they are capable of inhibiting the production of crops to the extent of crop failure. Although it is recognised that weed populations have important ecological functions, weed control in organic arable cropping is often cited as a major constraint on organic production.

However, the principles of organic farming don't necessarily align with the conventional strategy of 'dominance over weeds'. This produces a dilemma of balancing the need for weed management with maintaining and enhancing biodiversity.

Much has been written on the theory of organic weed management but does the practice of organic weed management in the UK reflect this? It's possible that farmers' collective knowledge may be useful in designing successful organic arable weed strategies. A survey of the weed control strategies of cross section of UK arable farmers may identify whether there are critical factors or techniques?

Review of organic arable weed management

Effect of weeds on crops

Weeds are often defined as a plant out of place or a plant that causes economic or ecological damage or loss. However, definitions of weeds are subjective and are greatly influenced by one's attitude. Weeds are ever-present in most crops as agricultural soils usually contain numerous weed seeds and, if left unmanaged, weeds can greatly reduce crop yields by competing with the crop for nutrients, light and water as well as potentially reducing the value of harvested crops and physically impeding the harvest process.

Yield loss due to weed competition is estimated at 34% worldwide, although it can be difficult to determine accurately due to the complex effects and interactions of soil type, nutrition and moisture availability.

The yield loss will also depend on the degree of weed management being used. In intensive systems, losses could be as low as 5%; whereas in less intensive, non-herbicide systems (such as organic farming) losses could exceed 25%. It is generally accepted that there is a negative correlation between weed populations and crop yields.

Weed species

Weed diversity and the differing competitive abilities of weed species make it difficult to evaluate the relative importance of individual weed species causing yield loss, which can be mitigated by weed diversity as this reduces the probability of the occurrence of dominant and competitive species.

In organic farming in the UK, docks charlock, wild oats and creeping thistle, couch grass, and mayweed are widely regarded as the most problematic weeds.

Benefits of weeds

Despite the potential yield sapping effect of weeds, they do possess beneficial aspects. Weed diversity can be an indication of the wider sustainability of the whole cropping system as plants are one of the key components of terrestrial ecosystems. Major declines in other wildlife can occur if too many weeds are removed from farm land as weed populations can provide food and habitat for a range of beneficial organisms. For example, the seeds of arable weeds predominated in the diets of bird species typically found in farmland areas across Europe and a number of invertebrate groups, which arable weeds support, are often an important food source of many bird species.

Weeds can also act as a natural green manure and they can also act as indicators of soil structure issues or nutrient disorders; the weed growth reflecting the soil type to which particular weed species are adapted.

Principles of organic weed management

Organic farming is an holistic production system that aims to promote and enhance agro-ecosystem health, thus to maintain weed populations at a manageable level, whilst also paying due regard to the organic principle of maintaining and enhancing biodiversity.

Effect of weed management strategies and methods

There are two main categories of weed management strategies. Firstly, cultural or preventative management, such as: cropping sequence, crop and cultivar choice, pre-crop cultivation, crop establishment, and weed-seed hygiene. Secondly, direct or reactive weed management with the aim of physically removing or damaging weeds to prevent growth and/or weed seed dispersal.

Cultural or preventative weed management

Crop rotation

Crop rotation, as a strategy to suppress weeds, is based on crop sequences that create varying patterns of competition that prevents the proliferation of dominant weed species.

Generally, rotations that employ diverse weed management practices and contain crops with differing phenology are most effective at disrupting the growth of the greatest number of weed species. Likewise, longer rotations have also been found to reduce seedbank populations in organic production systems.

Cover crops

Cover crops, such as green manures and catch crops, as well as benefiting the soil, can also aid weed control by providing competition to weed growth. A vigorous cover crop can suppress weed growth.

Crop choice and cultivar

Selecting for factors that enhance crop competitiveness provides the most effective weed management. Traits associated with competitive ability include early season vigour, plant height, and early maturity.

However, organic farmers mainly rely on cultivars developed for conventional farming systems, where many of the desired traits that will benefit the cultivars when grown organically are not given sufficient priority. This has led to calls for a separate organic breeding programmes but the relatively small market offered by organic agriculture has not generated enough interest in establishing specific breeding programmes.

Cultivation method and establishment

Mouldboard ploughing is the most common method of seed bed preparation in organic farming, considered a more dependable option than non-inversion tillage. However, there is an increasing in conservation tillage practices and/or reduced tillage in organic systems to enhance soil health.

Seed rate and sowing date

Increasing the crop density by increasing the seed rate is considered one of the best options for in-crop weed management. Sowing date also has an effect; for example in winter cereals, earlier sowing resulted in greater weed burdens but delaying sowing to reduce weed burdens has to be considered alongside the risk of failing to establish a crop.

Stale seedbeds and cultivated fallows

The use of stale seedbeds has been shown to contribute to a decrease in the soil seedbank but results can vary according to weather conditions. Inclusion of a fallow in the rotation has been shown to reduce perennial weed numbers although both techniques should be used cautiously as excessive cultivation can result in soil and environmental degradation.

Direct weed management

Tine weeding

Reductions in weed density as a result of tine weeding are often variable and can range from 5% to 90% depending on the weed species present. It does not always result in a positive yield response and can result in crop damage as the technique has low plant selectivity.

Inter-row hoeing

Inter-row hoeing has been found to be more effective on tap-rooted and erect weed species than tine weeding, but if timing is compromised it can result in yield losses due to the wider row spacing allowing subsequent vigorous weed growth.

Hand weeding

Hand weeding is still advocated by as an effective method for controlling small numbers of weeds so as to prevent larger populations developing, usually a technique deployed against the more difficult to control weeds such as docks and wild oats. However, the number of hand weeding hours required per hectare can often make it an expensive and time consuming exercise if weed numbers are high.

Electrical weed control

The concept of using electrical energy to kill weeds was first developed in the late 1800s but has not proved cost effective when compared to other forms of weed management. More recently, developments using small robots equipped with electricity to kill weeds suggest the technique could potentially allow selective, non-chemical weed control suitable for organic systems.

Preventing seed return at harvest

Limiting seed return to the field could be an effective tool for organic farmers but it is only effective on weeds that retain seeds until harvest. Chaff collection systems and seed destructors are often used on combine harvesters in Australia but there is little data to suggest that their use is common on UK organic farms.

Farm weed seed hygiene

Weed seeds can be spread between fields on machinery and as a contaminant of animal feed, seed, manures and purchased inputs. Preventing the spread of weed seed by exerting high standards of farm hygiene is considered an important preventative measure and it is likely that most farms exercise farm hygiene to some degree but probably to varying standards.

Organic weed management strategy

There is a consensus in organic weed management literature that a hierarchy of techniques when designing an organic weed management strategy should be: cropping sequence or rotation, crop and cultivar choice, cultivation choice and establishment method, and lastly, direct weeding. Organic weed management cannot be just approached from a direct reductionist perspective but should be integrated within the whole production system; direct weed control is only likely to be successful if used in conjunction with preventative weed management measures as well.

Organic weed management in the UK

There is little research data about the use of organic weed management practices in the UK, only two sources were identified. A survey in 1999 highlighted crop rotation as the most popular technique of weed management although most farmers surveyed thought their weed control was moderately effective. The fact that farmers viewed weed control as imperfect implied there was a need to develop more effective techniques.

Later, a 2007 survey questioned whether the plethora of research on non-chemical weed control addresses the needs of farmers and/or the development of organic systems? This survey, found that a majority of respondents had concerns about weed management and weed numbers. Although, those who had been organic for longer were more relaxed in their attitude to weeds; possibly indicating that as farmers develop their own system, they become less indiscriminate about weeds. Many farmers did some form of their own practical research as well as investigating techniques used by other farmers.

Survey design

The review established the principles and significant factors of organic arable weed control, providing a basis on which to decide which information is relevant and important in understanding how organic arable farmers manage weeds.

An on-line questionnaire was judged to be the most suitable means of collecting the required data and appropriate when the characteristics of the target audience of organic arable farmers in the UK were taken into consideration. The questionnaire was distributed as a hyperlink, via organic certifying bodies in the UK, the Organic Research Centre, the National Farmers Union the Organic Arable Marketing Cooperative, and the Institute of Agricultural Management. Additionally, individual farms (whose e-mail addresses were accessible on-line) were sent an explanatory request and the hyperlink. The survey was conducted in Dec 2020 and January 2021.

Results

Responses and respondents

The questionnaire yielded 64 responses covering a total area of 24183ha. This represents about 8% of organic arable farmers or, 26% of the organic arable area. The farm size ranged from 35 to 2000ha with an average of 378ha, growing an average of 157ha of combinable crops. This compares with the average UK organic farm of 134ha and the average area of organic arable crops grown of 49ha.

The majority of the land represented in the survey was fully organic and the mean average number of years farmed organically was 16 with 50% of farms having been organic for 20 years or more. Most farms had some livestock, less than 10% were stockless. Most respondents were farmers rather than advisors or managers with usually more than 10 years of organic experience.

Rotation

Growing four crops in the rotation was most common with the average being five (Figure 1). Spring cereals occurred in nearly all rotations, short term grass/cover leys and winter cereals were in more than two thirds of rotations (Figure 2). Consequently, the most occurring combination of crops was short term grass/cover leys, spring cereals and winter cereals.

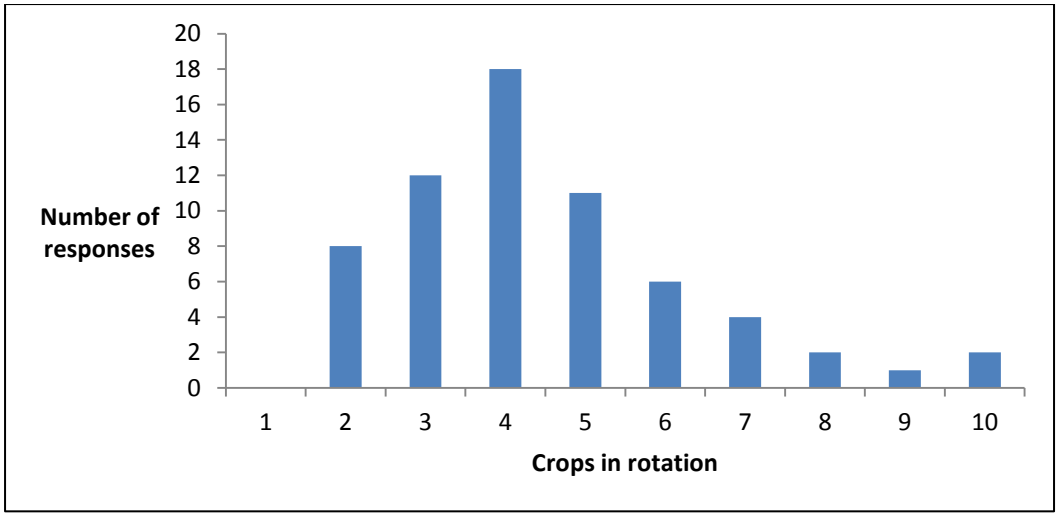

Figure 1. Number of crops grown in the rotation. *N* = 64.

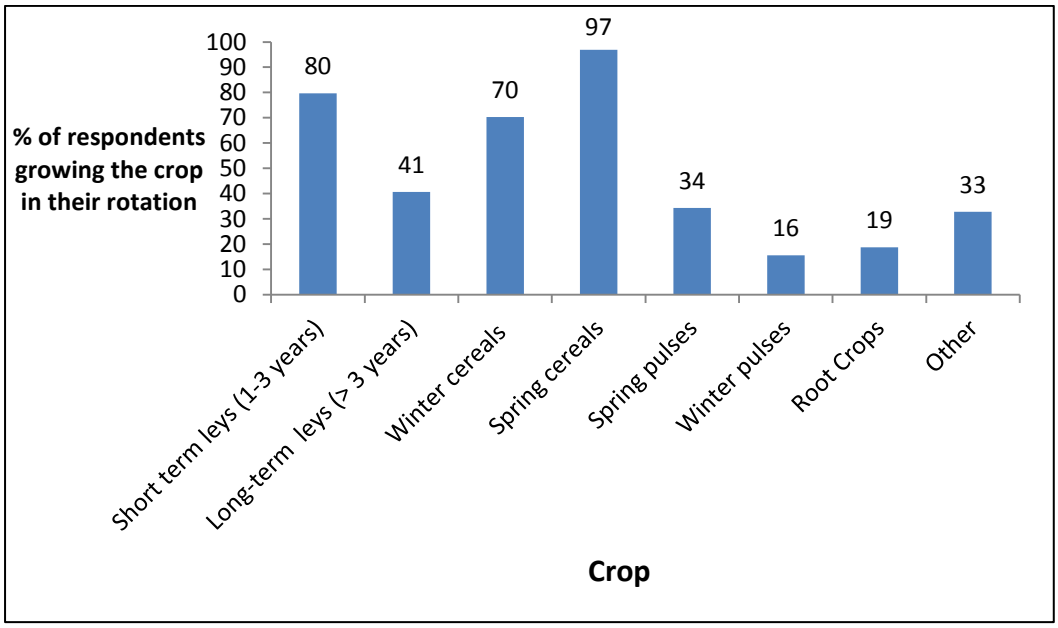

Figure 2. Frequency of a crop being included in a rotation. *N* = 63.

As part of their rotation, the majority of respondents (73%) grew cover crops at least sometimes and most of these crops were grazed. The regular use of cultivated fallows was uncommon with only 14% of respondents frequently or always using them; whereas the use of stale seedbeds was more common, 47% of respondents frequently or always used them.

Arable Crops

Most respondents reported that docks were their most problematic weed (Figure 3). Next, creeping thistle, charlock and couch grass were judged as equally as problematic as each other and wild oats were ranked as the most problematic grass weed.

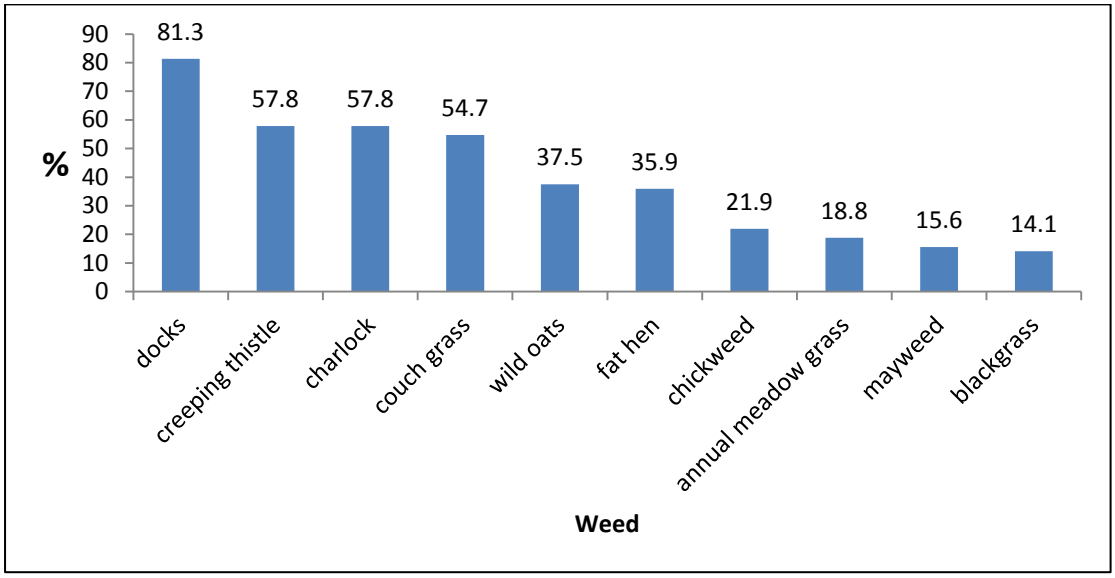

Figure 3. Percentage of respondents selecting a weed as problematic. *N* = 64.

When establishing their arable crops, most respondents (75%) used the plough, only one used direct drilling and when planting crops, nearly 94% used increased seed rates as a weed management measure. With regard to factors that might be considered when choosing varieties of arable crops, respondents selected weed competiveness as the most important. Yield potential, quality (with regard to the end market) and disease resistance were similarly ranked. Although crop structure characteristics (height and growth type) were selected as less important. (Figure 4).

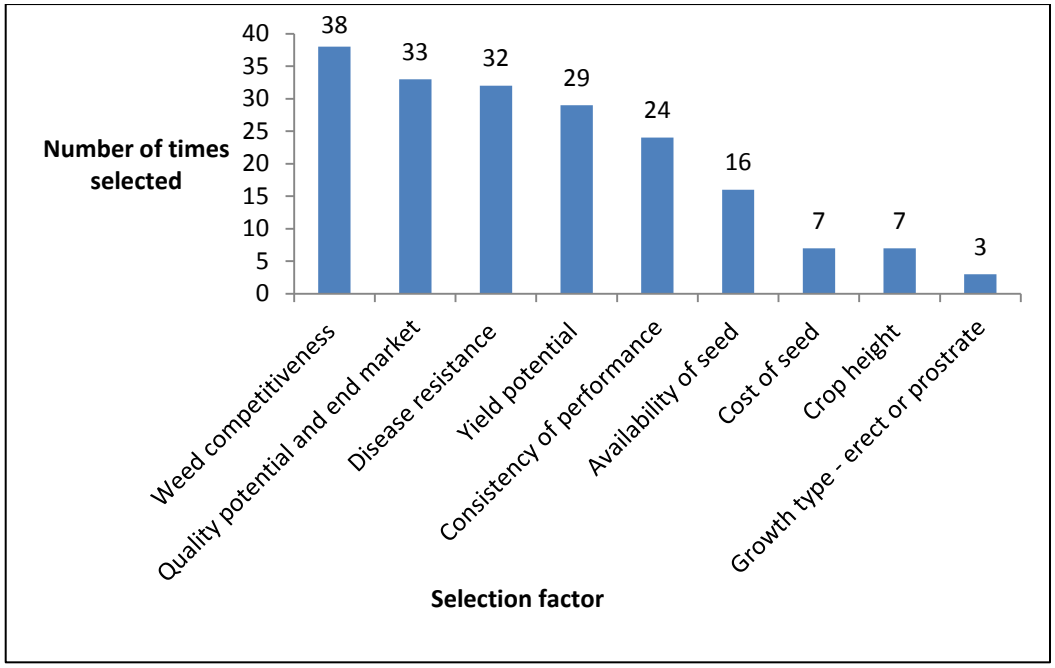

Figure 4. Importance of factors when choosing varieties of arable crops. *N* = 64.

Weed harrowing was the most common method of in-crop weed control most used in both crop types at over 70% (Figure 5). The next most used method was hand weeding in cereals and inter-row hoeing in pulses. A notable percentage of farmers of either crop used no direct weed control.

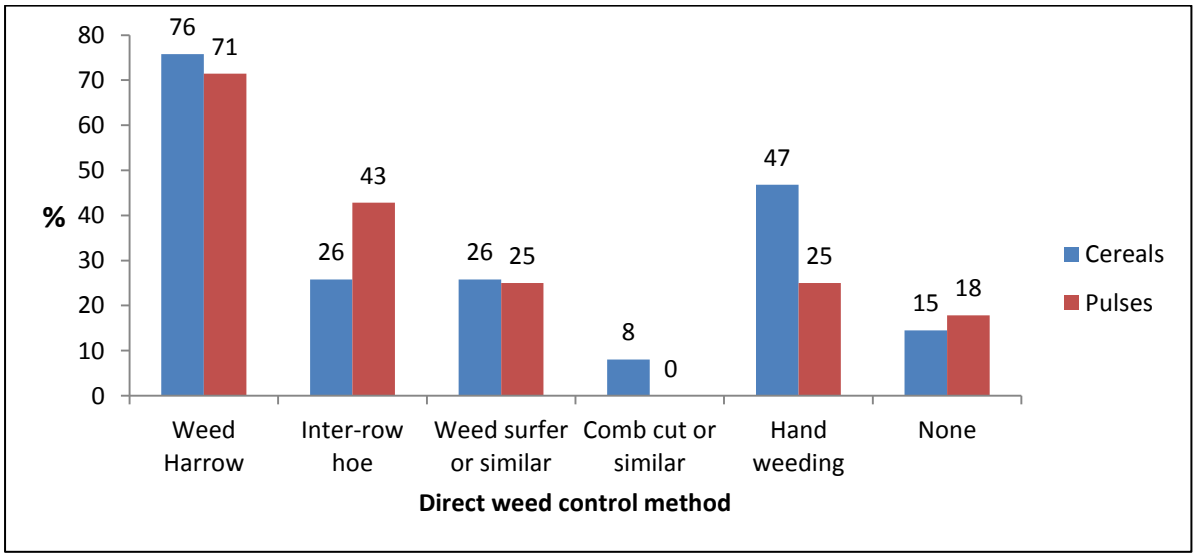

Figure 5. Percentage of respondents (who grew the crop) using direct control methods. *N* = 64 for cereals. *N* = 28 for pulses.

Strategy

Rotation design was selected the most important factor in strategy design (Figure 6). Seed bed preparation and establishment, and seed rate and planting date were the next most highly ranked. Variety choice was the second lowest ranked factor.

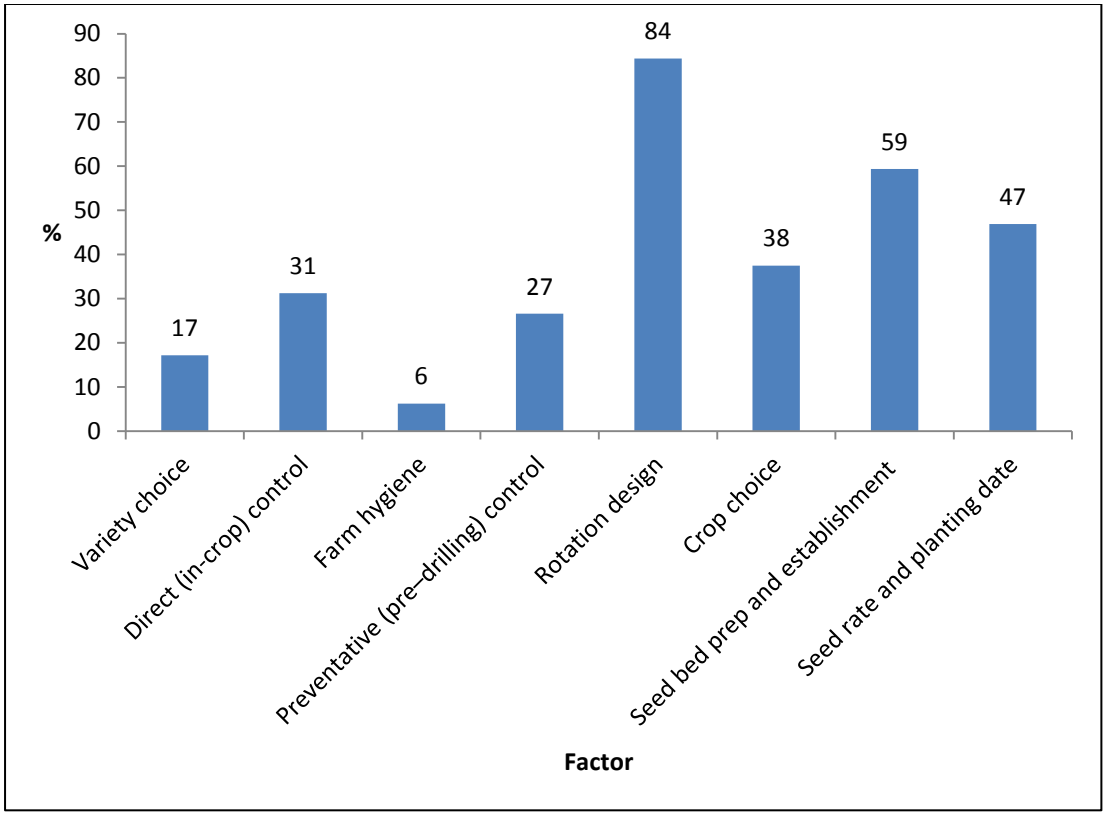

Figure 6. Frequency of selection of importance of factors in weed management strategy. *N* = 64.

Using a Likert scale to gauge the effectiveness of their weed management strategy, over half of respondents (54%) thought theirs was moderately effective. With this as the mid-point, slightly more respondents gauged their strategy to be more ineffective than effective (Figure 7).

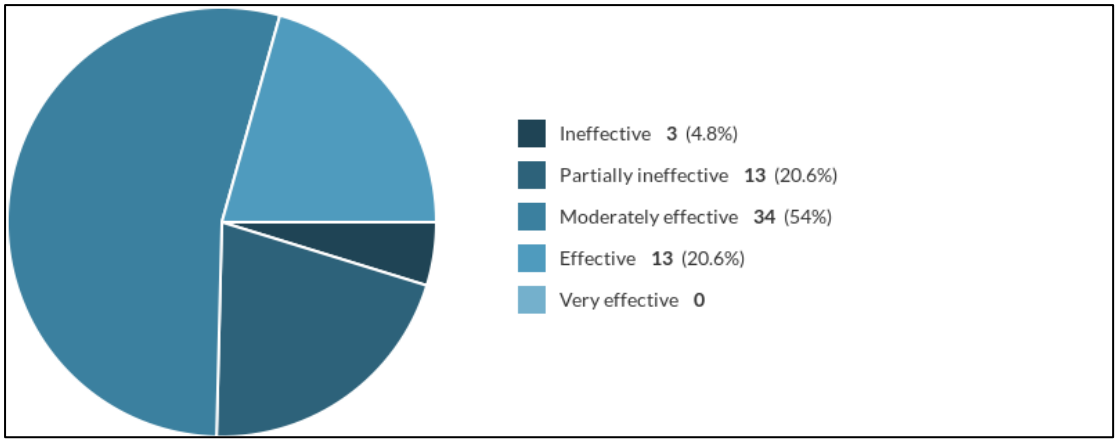

Figure 7. Respondents' judgement of the effectiveness of their weed management strategies. *N* =63.

With regard to weed density in their arable crops (the number of weeds per unit area), respondents judged it to have increased more than decreased over time (Figure 8).

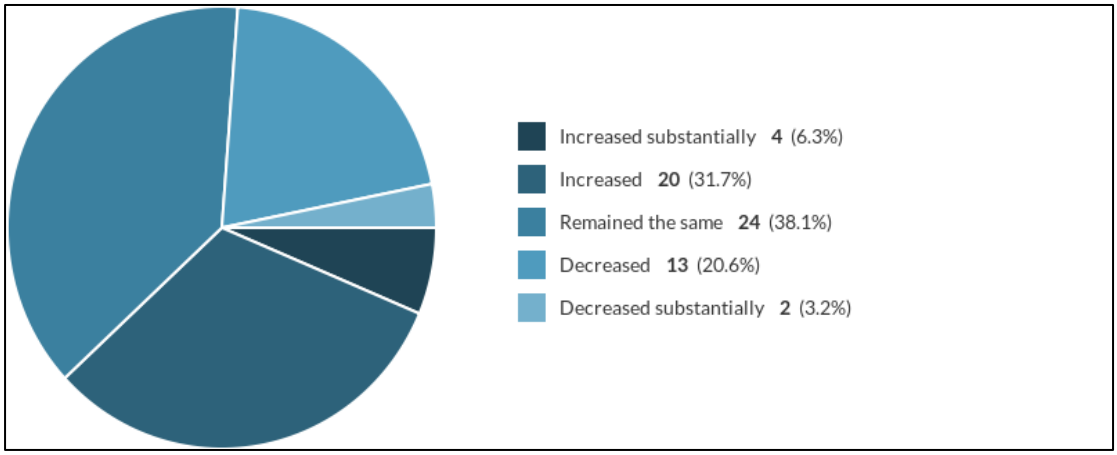

Figure 8. Respondents' judgement of the changes in weed density in their organic arable crops. *N* = 63.

During their time as organic farmers, the majority of respondents became more tolerant of weeds (Figure 9) although there was no statistical significance between the number of years as an organic farmer and attitude to weeds (Appendix D).

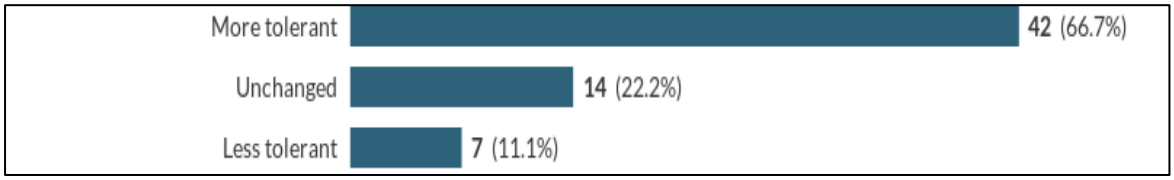

Figure 9. Respondents' changes in attitude to weeds. *N* = 63.

The respondent's most important sources of information on organic weed control were their own experience and knowledge of other farmers. Agronomists and advisors and discussion groups were the least important source of information (Figure 10).

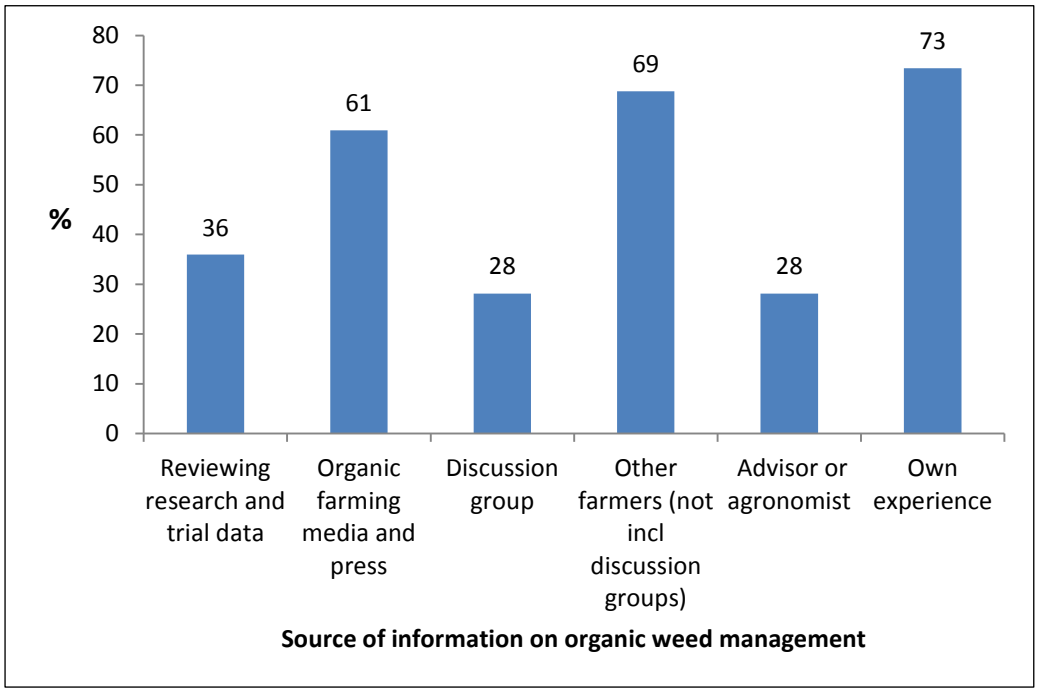

Figure 10. Respondents' sources of information on organic weed control. *N* = 64.

A final question asked respondents to add any comments or observations they had about weed management in their arable crops. Most comments were about mechanical weed management and more were negative than positive, either the lack of effectiveness, and therefore cost effectiveness, or regarding the possible negative impacts of mechanical weeding on flora and fauna.

Designing long rotations which include forage break crops and cover crops was mentioned as having a positive impact on weed management. The use of livestock and the weed management opportunities offered by grass management were also mentioned as being useful for weed control.

The importance of establishing competitive crops and timeliness of operations received twelve positive mentions; they were viewed as significant factors in the respondent's ability to successfully manage weeds.

Discussion

Rotation

Most farmers were growing four crops in their rotation. Maybe this is a practical optimum as growing too many crops could over complicate the farming system to the point where the crops are not managed well enough?

Spring cereals featured in nearly all rotations. It is sometimes considered that spring sown cereals are more competitive than winter sown cereals but whether that is the main reason for their popularity is unclear. Pulses featured in less than half of the rotations; possibly not as popular as might be expected in organic rotation when considering the agronomical benefits of pulses in terms of nitrogen fixing ability and a disease break for cereal crops? However, pulse's relatively slow establishment and lack of vigour can mean they are often out-competed by weeds.

Most farmers grew a perennial crop in the form of a grass/clover ley; forage crops with high ground cover are thought particularly competitive with weeds numbers and also provide a cutting/mulching opportunity for weed control and grazing in a crop rotation can provide a contrasting selection pressure to other weed control options.

Cover crops were commonly grown. These can aid weed control whilst enhancing soil health and sometimes reduce the need for tillage which can result in negative impacts on soil health.

Weed species

The weed species selected by respondents as being the most problematic were very similar to those identified in the review. Other than wild oats, grass weeds seem to be less of a

problem in organic systems, probably as a result of the widespread use of grass/clover leys and ploughing.

Crop management

The main cultivation system was predominately the use of the plough. This seems to be in contrast to recent trends in cultivation on conventional farms where the use of ploughing is becoming less common. The motivations for reduced tillage on conventional farms are reduced input costs and improvements in soil condition. The motivations for organic farmers are probably the same but organic farmers are possibly reluctant to use reduced tillage because of possible increases in weed burdens. Reductions in the frequency and intensity of tillage may be a more achievable option.

When asked to rank selection criteria for choosing varieties of arable crops, weed competitiveness was the most popular choice. This is interesting in that there is very little information (if any) available to farmers as to which varieties compete best with weeds and surprisingly, respondents did not rank crop height and growth type highly despite these characteristics being linked to competitive ability.

The popularity of weed harrowing may be due to its ease of use, versatility and relatively low capital cost compared to other weed control machinery such as inter-row hoes and above -crop cutters. However, the cost effectiveness of weed harrowing is not always clear, whether the use of weed harrowing has become habitual or its use is based on weed thresholds, which could give an indication of cost effectiveness, is not known.

Strategy

Respondents ranked the top four factors of importance in their weed management strategy as: rotation design > establishment method > crop choice > direct control. This is fundamentally the same as per the review, demonstrating that the strategic principles of organic weed management are probably well understood but how farmers have come to this understanding is unclear. When asked what were their most important sources of information on organic weed control, respondents chose their own experience as being their most important indicating that perhaps farmers have established their strategy through their own endeavours. Research data and advisors were ranked as much less important sources of information.

Weed management in arable crops was judged to be no more than moderately effective by the majority of respondents. These judgements are very similar to those found in previous surveys. This could suggest that organic weed management has plateaued for 20 years?

Notwithstanding their difficulties in managing weeds, the biodiversity benefits and soil protection offered by weeds were recognised. This might be expected of organic farmers, whose guiding principles are to minimise their effect on the environment.

Respondents felt most constrained by the cost effectiveness of weed management operations. The issue of cost effectiveness is not new, it was observed whilst compiling this study that evaluation of weed management techniques often seems to be judged on crop yield and weed densities without always considering the costs of implementation versus the financial gains.

Despite the constraints as to what can be achieved with regard to weed management, when asked to consider how their attitude to weeds had changed during their years as organic farmers, most respondents were more tolerant of weeds. It could be that farmers have become accepting of their weed management situation, based on the presumption that they could see that their farm was not over-run with weeds and their management methods were effective enough to achieve a balance.

Respondents' comments on weed management

Mechanical weeding generated many comments and the views were mixed. Several thought mechanical weed control to be not cost effective, detrimental to biodiversity in terms of weed diversity because of its non-selective nature and catastrophic to ground-nesting birds. Consequently, they had reduced or even stopped their mechanical weeding operations.

Likewise views on cultivations were also mixed, indicating that some farmers are uncomfortable with the negative aspects of cultivations but weed management requirements compel them to cultivate. Even so, it was also suggested that having a range of cultivation methods was a useful management technique which may also offer the ability to reduce the intensity and frequency of cultivations.

Conclusion

The study has shown that generally, UK organic arable farmers use weed management strategies that are very similar to those described in the review. In that they recognise the hierarchy of weed management strategy by adopting long, diverse rotations that include a perennial crop (in so far as avoiding complexity will allow); they endeavour to establish competitive crops, most commonly using a plough based system, and more often than not they grow cover crops. However, they judge their weed management to be no more than moderately effective. When compared to previous studies, this opinion appears not to have changed in recent decades suggesting that weed management may have reached a plateau. The study suggests that the currently available techniques for organic weed management are probably as effective as they can be but are not entirely balancing the need for weed management with maintaining and enhancing biodiversity.

It has not proved possible to determine which strategies and techniques are more successful than others with the data collected in this study, but the fact that some strategies and techniques in particular (as highlighted in the previous paragraph) are practiced by the majority of respondents and that most of farms and respondents have been organic farms or organic farmers for more than a decade, suggest that the most commonly used practices have proved to be the most effective over time.

That is not to say that organic weed management cannot or should not be improved. It is apparent that there is a need for renewed thinking and new initiatives which aim to maintain weed diversity whilst reducing weed density. New technologies, such as robotic weeders with vision-based capabilities of weed detection, classification and elimination are

being developed which may be part of the solution, subject to capital cost and therefore cost effectiveness.

Factors such as breeding crop varieties with weed competitive traits suitable for organic farms, reducing the negative impact of cultivations on soils in organic systems and the need for more certainty over the cost effectiveness of organic weed management (direct weed management in particular) deserve particular attention.

The issue of cost effectiveness is not new and has also been identified in previous studies. Organic weed management research should ideally be longer term to match the long term nature of organic systems and with more emphasis on cost effectiveness. The subsequent research findings ought to be more accessible to farmers as, at present and historically so, their main sources of information on organic weed management are their own experience and that of other farmers; suggesting that research findings are not reaching those who are the intended beneficiaries. To this end, it is intended that the study's findings are disseminated to organic farmers to draw attention to the subject of organic weed management and promote debate.

This study has given a broad view of the weed management practices used on UK organic arable farms but has arguably provided more questions than answers. It has however highlighted aspects of weed management which farmers think are most constraining or are of most concern. These areas should be the subject of more detailed surveys. This could potentially provide farmers with accessible data that offer cost effective, adoptable solutions.