A comparison between the impacts of ploughing and minimum tillage on arable plant assemblages at Ranscombe Farm Reserve, Kent, UK

Richard I. Moyse[1]* & Catharine Shellswell[2]

[1] *Plantlife, Ranscombe Farm Reserve Office, Court Farm, Upper Halling, Rochester, Kent ME2 1HR, UK*
[2] *Plantlife, 14 Rollestone Street, Salisbury, Wiltshire, SP1 1DX, UK*

SUMMARY

Land at Ranscombe Farm Reserve showed a build-up of biennial and perennial plants following a number years of conservation management for rare arable plants. The impacts of two different forms of cultivation were compared in order to understand how cultivation might be used to control this build-up, while maintaining the habitat for the rare arable plants for which the site is important. It was found that, in comparison with minimum tillage, ploughing produced lower overall plant cover but had no significant impact on the numbers of annual plant species, or on the number or population size of rare annual plant species. Plants considered to be problem species, such as creeping thistle *Cirsium arvense* and perennial sowthistle *Sonchus arvensis*, were not affected by the type of cultivation, but the abundance of these species did not appear to have a negative impact on those annual arable plants of conservation concern.

BACKGROUND

Ranscombe Farm Reserve, Kent, UK is a 250 ha area of arable, woodland and grassland managed by the charitable organization Plantlife. It was established as a nature reserve in 2005 following its acquisition by a partnership of Plantlife and Medway Council. This site has long been known to support an exceptionally rich arable flora, including corncockle *Agrostemma githago*, ground-pine *Ajuga chamaepitys*, blue pimpernel *Anagallis arvensis* ssp. *foemina*, stinking chamomile *Anthemis cotula*, dwarf spurge *Euphorbia exigua*, Venus's-looking-glass *Legousia hybrida*, hairy mallow *Malva setigera*, prickly poppy *Papaver argemone* and rough poppy *Papaver hybridum*, as well as more common arable plants. Prior to the site's establishment as a nature reserve, management for arable wild plants was largely confined to one field, Kitchen Field, which forms part of the Cobham Woods Site of Special Scientific Interest. Since this time, further areas of previously conventionally managed arable farmland have been brought into conservation management, so that, at the time of the study, two large blocks (4.6 ha at Kitchen Field, plus 3.9 ha at Longhoes Field, approximately 1.5 km to the east) were being managed specifically for rare arable wild plants, together with an approximately 1,950 m length of margins in otherwise conventional arable fields.

The arable land in conservation management at Ranscombe is managed by the site's tenant farmer under Environmental Stewardship options. At the time of the study:

- Kitchen Field and Longhoes Field were managed by annual cultivation followed by sowing of a cereal crop, but with no applications of fertilisers, manures or herbicides.
- Arable field margins were managed by annual cultivation, but remained unsown and received no fertilisers, manures or herbicides.

Management of the conservation arable fields and margins is generally by minimum tillage (min-till), the ground being broken up by repeated passes of a disc harrow. This results in the ground being disturbed only to a depth of around 5 cm, and not inverted; this is in contrast to ploughing, which breaks up the ground to a depth of around 15 cm, and inverts the soil. It had been noted, after four years of implementing Environmental Stewardship options, that there was a build-up of biennial and perennial plants, including extensive populations of bristly oxtongue *Helminthotheca echioides*, hawkweed oxtongue *Picris hieracioides*, and perennial sowthistle *Sonchus arvensis*. This was thought to be the result of continuous minimum tillage, and that ploughing might offer a method of control and reduction of biennial and perennial species, and an associated increase in the diversity and population sizes of the annual plant species which are the target of conservation management in the arable fields. An experimental study was undertaken over two years to compare the impacts of ploughing and minimum tillage upon annual plants, particularly rare arable plants, perennials, and problem weed species.

ACTION

The study areas consisted of two fields at Ranscombe Farm Reserve (Kitchen Field and Longhoes Field), and approximately 600 m of a 6 m wide cultivated margin at Ranscombe Farm Reserve (Fifty Acres Field). All of the study areas were used in the first year of the study, but only Kitchen Field and Longhoes Field were used in the second year.

The treatments received by the different study areas are set out in Table 1; in summary, they were as follows:

- Kitchen Field and Longhoes Field were each divided into two halves. In the first year, one half of each field was cultivated by ploughing, harrowing and sowing with a cereal crop, the other by minimum tillage and sowing. In the second year, the treatments were swapped, so that the half which was previously ploughed received minimum tillage, and *vice versa*.
- A 600 m stretch of the 6 m-wide cultivated margin of Fifty Acre Field was divided into blocks of 100 m length, with blocks being alternately ploughed and harrowed, or

* To whom correspondence should be addressed: richard.moyse@plantlife.org.uk

ISSN 1758-2067

Table 1. Cultivation treatments in each of the study areas in each year.

Study area	Treatment year 1	Treatment year 2
Kitchen Field	Southern half min-tilled and sown with wheat in April 2013. Northern half ploughed and harrowed, then sown with wheat in April 2013.	Southern half ploughed and harrowed, then sown with wheat in March 2014. Northern half min-tilled and sown with wheat in March 2014.
Longhoes Field	Southern half min-tilled and sown with wheat in April 2013. Northern half ploughed in October 2012, followed by harrowing and sowing with wheat in April 2013.	Southern half ploughed and harrowed in March 2014, then sown with wheat in April 2014. Northern half min-tilled in March 2014, then sown with wheat in April 2014.
50 Acre Field	Three 100 m sections, each 100 m from the next, ploughed in October 2012, then the full 600 m length thoroughly harrowed in April 2013. Not sown.	No action

cultivated by minimum tillage. This area was not sown with a crop.

Monitoring plots consisted of a transect 50 m long by 6 m wide located at least 10 m from any field corners and lying directly adjacent to the field boundary. Within each transect, two parallel lines of five quadrats were placed, one line at 2 m from the field boundary and the other at 4 m. Quadrats were spaced 10 m apart (i.e. 5 m, 15 m, 25 m, 35 m and 45 m from the end of the transect) and each quadrat measured 0.5 m by 0.5 m (Figure 1).

For each quadrat, the following data were recorded:

- A list of all vascular plant species present (Table 2).
- The percentage cover of a suite of plants considered to be problem weeds (Table 2).
- The percentage cover of bare ground.
- A count of the number of individuals for any of a list of rare annual plants (Table 2).

A total of 16 transects (160 quadrats) was surveyed during August 2013, and 10 (100 quadrats) during August 2014. Of these transects, four were in Kitchen Field (two in each half), six in Longhoes Field (three in each half), and six in the margin of Fifty Acre Field (one in each of the three ploughed blocks and the same in the minimum tillage blocks); all the transects were surveyed in 2013, but only the transects in Kitchen and Longhoes Fields in 2014.

Data from the two years were combined prior to analysis. Comparisons between ploughed areas and areas under minimum tillage were analysed using a one-tailed t-test in the Analysis ToolPak included in Microsoft Excel 2007. For the purposes of the t-test, data for the mean percentage cover of bare ground and problem weeds were transformed using base-10 logarithms to approximate the normal distribution, while figures for total counts of rare plant populations were square root transformed; figures were then back-transformed to give the reported averages. Because six different comparisons were made using the data, the Holm-Bonferroni sequential correction was applied to p-values, using a calculator based on Microsoft Excel (Gaetano 2013). Regression analysis was undertaken using the Analysis ToolPak included in Microsoft Excel 2007.

CONSEQUENCES

A total of 106 species were recorded in the survey. This included seven rare arable plants and 18 problem plants (Table 2). Table 3 shows the data recorded for each transect

Only one measure showed a significant difference between the two treatments, and this was the average bare ground cover, which was higher under ploughing (27.2%) than under min-till (10.2%) (Table 4).

The combined number of biennial and perennial species was lower, and the number of annual species higher, under ploughing, but these differences were not statistically significant once the Holm-Bonferroni correction was applied (Table 4).

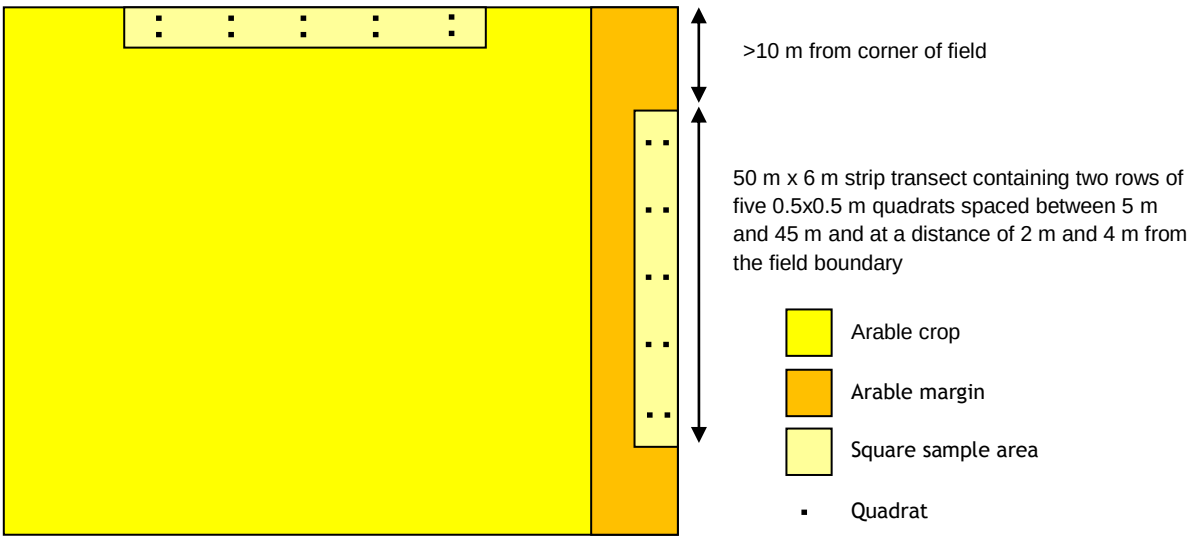

Figure 1. The arrangement of transects and survey quadrats within the study areas.

ISSN 1758-2067

Table 2. List of plants recorded across all surveys. (P) = Problem species, (R) = Rare species.

Fool's parsley *Aethusa cynapium*
Black bent *Agrostis gigantea* (P)
Creeping bent *Agrostis stolonifera*
Ground-pine *Ajuga chamaepitys* (R)
Meadow foxtail *Alopecurus pratensis*
Scarlet pimpernel *Anagallis arvensis* ssp. *arvensis*
Barren brome *Anisantha sterilis* (P)
Stinking chamomile *Anthemis cotula* (R)
Parsley-piert *Aphanes arvensis*
Lesser burdock *Arctium minus*
Thyme-leaved sandwort *Arenaria serpyllifolia*
False oat-grass *Arrhenatherum elatius*
Mugwort *Artemisia vulgaris*
Wild-oat *Avena fatua* (P)
Daisy *Bellis perennis*
Turnip *Brassica rapa*
Soft-brome *Bromus hordaceus*
Rye brome *Bromus secalinus* (R)
Shepherd's-purse *Capsella bursa-pastoris*
Fern-grass *Catapodium rigidum*
Common mouse-ear *Cerastium fontanum*
Small toadflax *Chaenorhinum minus*
Rosebay willowherb *Chamerion angustifolia*
Fat-hen *Chenopodium album*
Fig-leaved goosefoot *Chenopodium ficifolium*
Creeping thistle *Cirsium arvense*
Spear thistle *Cirsium vulgare*
Traveller's-joy *Clematis vitalba*
Field bindweed *Convolvulus arvensis*
Smooth hawk's-beard *Crepis capillaris*
Wild carrot *Daucus carota* ssp. *carota*
Viper's-bugloss *Echium vulgare*
Common couch *Elytrigia repens* (P)
Willowherb species *Epilobium* sp.
Dwarf spurge *Euphorbia exigua* (R)
Petty spurge *Euphorbia peplus*
Black-bindweed *Fallopia convolvulus*
Broad-leaved cudweed *Filago pyramidata* (R)
Common fumitory *Fumaria officinalis*
Cleavers *Galium aparine* (P)
Cut-leaved crane's-bill *Geranium dissectum* (P)
Ground-ivy *Glechoma hederacea*
Bristly oxtongue *Helminthotheca echioides* (P)
Hogweed *Heracleum sphondylium*
Perforate St John's-wort *Hypericum perforatum*
Sharp-leaved fluellen *Kickxia elatine*
Round-leaved fluellen *Kickxia spuria*
Prickly lettuce *Lactuca serriola*
Henbit dead-nettle *Lamium amplexicaule*
Red dead-nettle *Lamium purpureum*
Nipplewort *Lapsana communis*
Venus's-looking-glass *Legousia hybrida* (R)
Lesser swine-cress *Lepidium didymum*
Common toadflax *Linaria vulgaris*
Perennial rye-grass *Lolium perenne*
Pineappleweed *Matricaria discoidea* (P)
Black medick *Medicago lupulina*
Corn mint *Mentha arvensis*
Annual mercury *Mercurialis annua*
Field forget-me-not *Myosotis arvensis*
Red bartsia *Odontites vernus*
Common restharrow *Ononis repens*
Common poppy *Papaver rhoeas*
Opium poppy *Papaver somniferum*
Redshank *Persicaria maculosa* (P)
Timothy *Phleum pratense*
Hawkweed oxtongue *Picris hieracioides* (P)
Ribwort plantain *Plantago lanceolata*
Greater plantain *Plantago major*
Rough meadow-grass *Poa trivialis*
Knotgrass *Polygonum* sp.
Creeping cinquefoil *Potentilla reptans*
Salad burnet *Poterium sanguisorba*
Selfheal *Prunella vulgaris*
Creeping buttercup *Ranunculus repens* (P)
Wild mignonette *Reseda lutea*
Weld *Reseda luteola*
Curled dock *Rumex crispus*
Hoary ragwort *Senecio erucifolius*
Common ragwort *Senecio jacobaea*
Groundsel *Senecio vulgaris*
Field madder *Sherardia arvensis*
White campion *Silene latifolia*
Charlock *Sinapis arvensis* (P)
Hedge mustard *Sisymbrium officinale*
Black nightshade *Solanum nigrum*
Perennial sowthistle *Sonchus arvensis* (P)
Prickly sowthistle *Sonchus asper* (P)
Smooth sowthistle *Sonchus oleraceus* (P)
Common chickweed *Stellaria media* (P)
Dandelion *Taraxacum officinale* agg.
Field penny-cress *Thlaspi arvense*
Red clover *Trifolium pratense*
White clover *Trifolium repens*
Scentless mayweed *Tripleurospermum inodorum*
Colt's-foot *Tussilago farfara*
Common nettle *Urtica dioica*
Narrow-fruited cornsalad *Valerianella dentata* (R)
Common cornsalad *Valerianella locusta*
Green field-speedwell *Veronica agrestis*
Wall speedwell *Veronica arvensis*
Common field-speedwell *Veronica persica*
Grey field-speedwell *Veronica polita*
Tufted vetch *Vicia cracca*
Field pansy *Viola arvensis*

No significant difference was found between the number of rare arable plant species under each treatment, nor in the cover of problem weed species, even before the applying the Holm-Bonferroni correction (Table 4).

The total population of all rare annual plants was higher under min-till (an average of 252 plants per transect) compared with ploughing (an average of 81 plants per transect), though this difference was not statistically significant once the Holm-Bonferroni correction was applied. The difference between the two treatments is mainly accounted for by two species, stinking chamomile and rye brome *Bromus secalinus* (Figure 2).

No relationship was found between the cover of problem weeds and either the number of annual plant species ($r = 0.013$, $p = 0.95$) or the number of rare annual plant species ($r = 0.15$, $p = 0.46$, Figure 3).

ISSN 1758-2067

Table 3. Data for each transect under both types of cultivation.

Field	Transect reference	Cultivation method	Year	Average cover (%)		Total number of species			Total population of all rare plants
				Bare ground	Problem weed species	Annual plants	Rare arable plants	Biennial & perennial plants	
Fifty Acres	FA3	Min-till	2013	8	1.5	6	1	7	401
Fifty Acres	FA4	Min-till	2013	6.5	2.6	4	1	10	971
Fifty Acres	FA6	Min-till	2013	3	11	5	1	11	51
Kitchen	KFNE	Min-till	2013	20.5	20.6	24	3	9	1279
Kitchen	KFNW	Min-till	2013	37.5	24	19	4	7	1024
Longhoes	LHSE	Min-till	2013	28.5	14.5	19	3	9	239
Longhoes	LHSM	Min-till	2013	9	6.1	20	3	12	118
Longhoes	LHSW	Min-till	2013	6.5	7.1	17	1	14	111
Kitchen	KFSE	Min-till	2014	6.4	67	9	4	15	20
Kitchen	KFS	Min-till	2014	35	20.1	15	3	12	291
Longhoes	LHNE	Min-till	2014	12.7	26.7	22	4	15	36
Longhoes	LHNM	Min-till	2014	7.7	6.3	25	3	16	57
Longhoes	LHNW	Min-till	2014	2.9	6.1	24	5	12	72
FiftyAcres	FA1	Ploughing	2013	25.5	27	20	1	8	2
FiftyAcres	FA2	Ploughing	2013	34	8.5	15	0	13	0
FiftyAcres	FA5	Ploughing	2013	47.5	31	18	2	6	9
Kitchen	KFSE	Ploughing	2013	14.5	64	24	4	14	230
Kitchen	KFS	Ploughing	2013	24.5	37.5	17	3	5	569
Longhoes	LHNE	Ploughing	2013	79.5	1.2	21	5	11	43
Longhoes	LHNM	Ploughing	2013	75	1	19	4	12	43
Longhoes	LHNW	Ploughing	2013	42	0.5	22	4	4	180
Kitchen	KFNE	Ploughing	2014	32.7	11.2	22	5	8	429
Kitchen	KFNW	Ploughing	2014	64	10.7	19	4	5	187
Longhoes	LHSE	Ploughing	2014	9.3	21.9	24	3	7	32
Longhoes	LHSM	Ploughing	2014	2.8	70	17	3	8	26
Longhoes	LHSW	Ploughing	2014	22	6.4	19	2	7	3

Table 4. Results of t-tests comparing ploughed transects with those under minimum tillage. P gives the unadjusted p-value, P' the Holm-Bonferroni corrected p-value.

Measure	Min Till	Ploughed	t	P	P'
Average cover of bare ground (%)	10.2	27.2	-2.99	0.006	0.034
Average no. of biennial and perennial species	11.5	8.3	2.31	0.020	0.098
Rare arable plant population size	252	81	-0.72	0.027	0.110
Average number of annual species	16.1	19.8	-1.85	0.044	0.133
Average number rare arable plant species	2.77	3.08	2.13	0.244	0.487
Average cover of problem weeds (%)	10.5	10.1	0.07	0.474	0.487

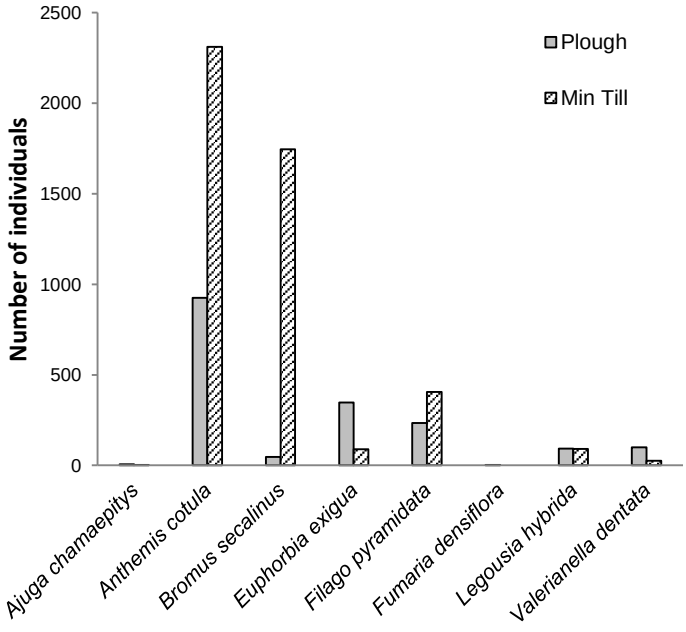

Figure 2. Total number of individuals for each rare plant species/transect under the two cultivation regimes.

ISSN 1758-2067

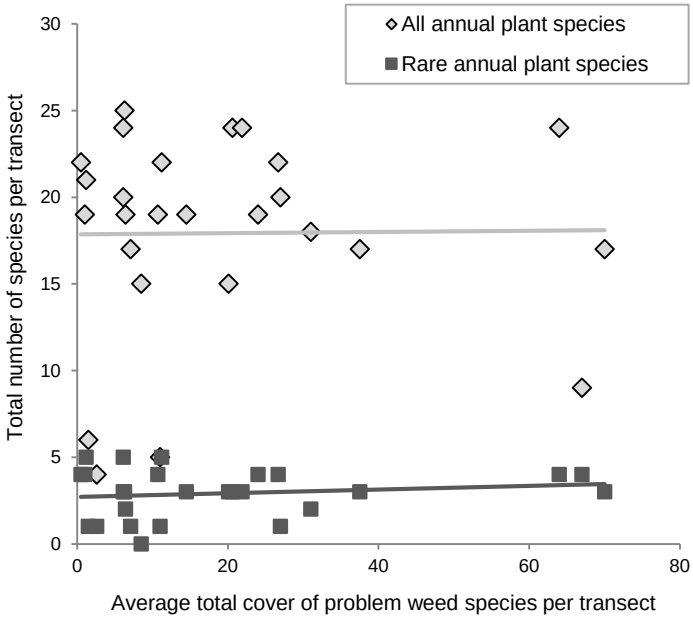

Figure 3. Number of annual plant species per transect against average total cover of all problem weed species per transect. For the upper regression line, r = 0.0126 and p = 0.95; for the lower, r = 0.152 and p = 0.460.

DISCUSSION

Ploughing created more bare ground. Three other measures showed a strong association with the type of cultivation, though none of the associations were statistically significant when the p-values were corrected for multiple testing. Nonetheless, there is at least a suggestion in the data that ploughing resulted in higher numbers of annual plant species, which might be expected given the availability of bare ground, and that minimum tillage resulted in higher numbers of biennial and perennial species, which might be expected as minimum tillage does not bury surface soil.

The other strong association was between the cultivation method and the overall population size of rare arable plants, and is not so easy to explain. It might be suggested that rye brome responded better to minimum tillage because it is an autumn germinating species (Wilson & King 2003). Minimum tillage undertaken in the spring would therefore have moved aside any seedlings rather than uprooting and burying them, which would have occurred in the ploughed plots. The biology of stinking chamomile is less well known. It is thought to be primarily spring germinating (Gealy *et al*. 1985), but there is some uncertainty regarding the germination period of the rarer sister species corn chamomile *Anthemis arvensis*, which may also be autumn and spring germinating (Wilson & King 2003). If stinking chamomile is an early spring germinating species, then minimum tillage would also be more suitable for this growth habit, and spring ploughing would reduce the number of seedlings that could develop into flowering plants.

The type of cultivation did not have an impact on the abundance of problem plants, meaning that ploughing was not found to be a better method of controlling build-up than minimum tillage. However, the absence of a relationship between the number of problem plants and either the number of annual plant species or of rare plant species suggests that the problem plants group may not, in fact, be an important issue from the point of view of arable plant conservation.

It is unfortunate that we were unable to properly compare autumn cultivation with spring cultivation, as all those areas in the trial which were cultivated in autumn also received additional disturbance in the following spring. Further research separating autumn and spring cultivation from minimum tillage and ploughing would be beneficial to target conservation management.

ACKNOWLEDGEMENTS

This work was funded through the INTERREG IVA France (Channel) – England European cross-border co-operation programme, which is co-financed by the ERDF. The assistance and support of Plantlife's tenant farmer, Andrew Lingham, and of Liam Rooney, are also acknowledged.

REFERENCES

Gaetano J. (2013). Holm-Bonferroni sequential correction: an EXCEL calculator. https://www.researchgate.net/publication/236969037_Holm-Bonferroni_Sequential_Correction_An_EXCEL_Calculator

Gealy R., Young F.L. & Morrow L.A. (1985). Germination of Mayweed (*Anthemis cotula*) Achenes and Seed. *Weed Science*, **33**, 69-73.

Wilson P. & King M. (2003). *Arable plants - a field guide*. WildGuides Ltd, Old Basing.

ISSN 1758-2067