Weeds as Bioindicators

A Farmer's Field Guide

Chris Maughan and Dominic Amos

Who is this guide for?

This guide is designed for farmers and growers wishing to undertake collaborative assessments of their soils as a way to learn about weed communities and soil health. The methodology has been designed with groups in mind, but it could equally be easily done solo. Beyond simple plant identification, the process requires no specialist knowledge to undertake, though the species guide itself does include some terminology. It is hoped that any meanings that aren't clear can be easily looked up, or provide discussion points with fellow participants. We hope above all that this may provide an entry point into the vast, enchanting, and under-researched world of plant bioindicators.

What are bioindicators?

Bioindicators are any living organism which can be used as a proxy for ecosystem condition. Here, we are focussed on 'weeds' (or non-crop plants) and what they can reveal about the soil properties in which they are growing. This approach is based on the idea that weeds don't just grow anywhere, but under specific 'germination conditions'. As such, if we observe weeds growing well and in significant numbers, we can make inferences about underlying soil type, structure and nutrient availability. Small numbers of single species are likely less useful bioindicators, in part because some species occupy very wide niches. For this reason the method described below is designed to identify 'weed communities'; i.e. groups of plants which thrive in the same conditions and that together give more reliable indications of underlying conditions.

How might they be useful?

Weeds as bioindicators could be useful (alongside other soil assessment methods) as a relatively inexpensive and convenient way for farmers and growers to assess the condition of their soils. Weeds as bioindicators could be used long term to monitor changes in soil health and impacts of soil management and cropping system changes. They could also be a way to build and share farmer knowledge and reduce dependency on external experts.

Equipment Needed

Clipboard, pen and survey forms
Plant ID tool (e.g. wild flower key/Plant ID app)
Hand lens (for plant identification)
Spade and tray (for soil assessment)

Method

Part 1

Plant identification

(20-30 minutes)

- In groups of four[1] spend about 20 minutes walking the field identifying all non-crop plants.
- Try to identify and rule out any plants that may have been put there deliberately (e.g. volunteer crops/green manures).
- Use a combination of own knowledge, identification apps (e.g. Plantnet), and field guides or plant keys.
- Write down all the species you find on the **Botanical survey sheet** (p.8) in the 'weed species' column.
- As you go, try to work out if the weed community is homogeneous or heterogeneous. If the latter, draw a simple sketch of the field to assign areas of clearly differing species (see Figure 1).

[1] The method described here was designed to be used by groups in order to aid collective learning and exchange; however, it can easily be done alone or in smaller groups.

Part 2

Cover/abundance survey

(90 minutes)

- Remain in groups of four. Sketch out the shape of the field and draw an 'M' to plan your route across the field (see Figure 1).
- Mark out 10 equidistant points along this route: these will be your cover/abundance sample locations.
- At the first location form a 'human quadrat'[2] (see Figure 2) and in the square formed between you identify all weeds present.
- For each weed, assign a percentage of the ground it covers and write it in the **Botanical survey sheet** (p.8) in the 'Soil % cover' column.
- For percentages, estimate the area covered by the entire plant, not just where it roots.
- Tip: try to reach a consensus between you; someone may underestimate, someone may overestimate, but together you will be more accurate. And above all be consistent, that way you can compare between fields/sampling events.
- Move on to the next sample point and repeat, entering data in the next column along each time.

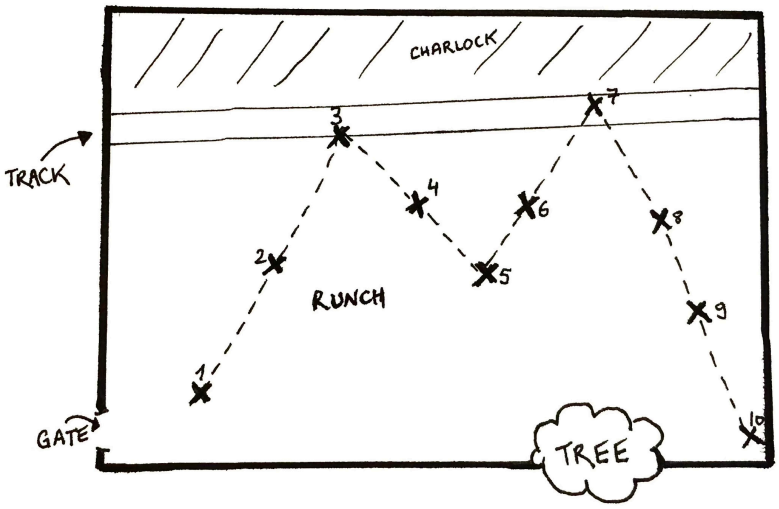

Figure 1. Example sampling route for cover/abundance survey

[2] If doing alone, a similar quadrat (or square) can be formed by using where you stand as the centre-point and identifying all plants that lie 1m behind, to the sides, and in front of you.

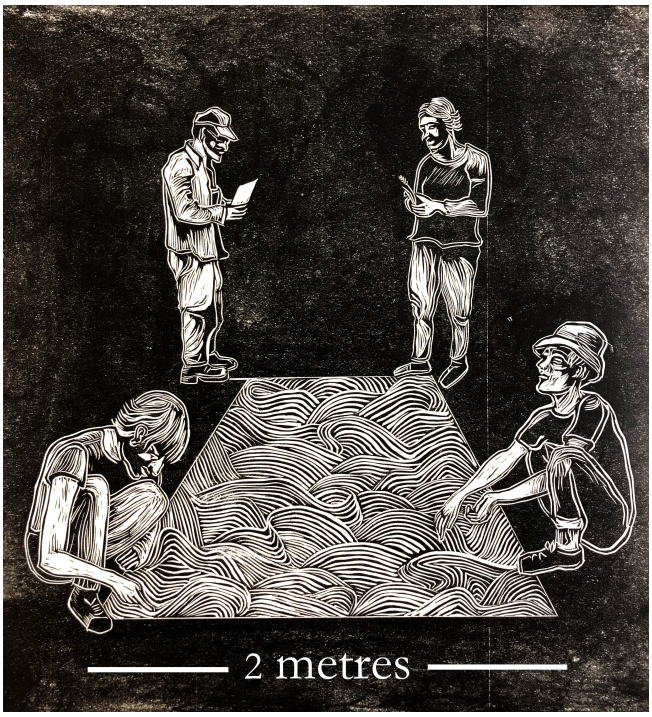

Figure 2. 'Human quadrat' sampling technique

Part 3

Bioindicators analysis sheet

(30 minutes)

- 'Eyeball' your botanical survey data to select the top five most abundant weeds.
- For each weed, sum and average the percentage ground cover.
- Then assign a score based on the following percentages:

  Less than 5% = 0
  Between 5-15% = 1
  Between 15-25% = 2
  Between 25-40% = 3
  Between 40-60% = 4
  Greater than 60 = 5

- Write the name of each weed in the **Bioindicators analysis sheet** (p.9) and its score in the 'Cover score' column.
- Using the **Bioindicators species guide** (pp.10-15), identify all the indications associated with each weed and write them in the 'Notes on soil properties' column to the right.
- Finally sum all the scores linked to each indication to get your final score.

For example:

Cover Score	Weed Species	Notes on soil properties and associations
3	1 Redshank (Persicaria Maculosa)	acid/low lime | high fertility/humus | waterlogged/poorly drained
2	2 Fat hen (Chenopodium Album)	high lime | high fertility/humus | surplus N | low P | high K
3	3 Couch grass (Elytrigia Repens)	compaction

For the above example:
high fertility/humus = 3 (Redshank) + 2 (Fat hen) = 5

The above example is also a good example of a 'weed community', in that Redshank and Fat Hen both indicate 'high fertility/humus'. On their own, their percentage cover wouldn't be high enough to meet our scoring threshold, but with their scores combined they do. This is one of the key advantages of this approach; that is, to control for biases which might lead us to notice one weed in one part of the field, or not notice others, thereby missing something important about what the 'community' as a whole is telling us. Any soil property which scores a '5' or above is considered to be a 'strong' bioindicator and merits further investigation.

Nb. These scores are purely indicative, meaning that they are intended to guide further investigation and (especially) continued monitoring. We recommend doing three surveys per year – i.e. in spring, summer, and at harvest – to see if results are repeated.

Part 4

Soil assessment

(20 minutes)

- Perform a visual assessment of soil structure.
- Compare your bioindicator hypothesis with the results of your soil assessment.
- We recommend using the VESS (Visual Evaluation of Soil Structure) method[1]:
    1. With a spade dig down to a depth of 40cm.
    2. Lift out a 10cm-wide slice of soil profile and place it on a flat surface (see Figure 3).
    3. Remove any 'smears' from the soil profile.
    4. Use the VESS criteria[3] to generate a score for your soil sample.
    5. Perform this again on any areas of surveyed field where you noticed a marked difference in weed abundance.

Figure 3. Soil profile sample taken with a spade and placed on a flat surface

[3] The VESS method and criteria can be found at
https://soils.vidacycle.com/soil-tests/vess-visual-evaluation-of-soil-structure
Soilmentor. (2020). VESS – Visual Evaluation of Soil Structure.

About our approach

Our approach has been inspired by the work of Gerard Ducerf, who has documented the 'indication characteristics' for over 800 weed species in his native France. We have adapted his methodology in numerous ways including focussing on weeds specific to the British Isles, and further systematising his scoring method. Many of these methodological updates emerged from a participatory study with farmers in June 2021. We have also combined a non-exhaustive selection of sources (including Ducerf (2014)) on bioindicators to assemble the **Bioindicators species guide** (pp.10-15). This resource is very much a first attempt, and we enthusiastically invite suggestions for improvement. Some known limitations exist; for example, some of the sources used contradict each other, and we have tried to highlight this where possible. This may be due to the different ecotypes on which they were based. In the UK, use of plant bioindicators as part of soil assessment is under-researched and considerable work remains to further investigate the reliability of the existing information. If you would like to get involved or learn more about this research please do get in contact.

Botanical Survey Sheet

Surveyor_____

Field/Farm_____

Date_____

Field Sketch Map

Cover/Abundance Scores
Less than 5% = 0
Between 5-15% = 1
Between 15-25% = 2
Between 25-40% = 3
Between 40-60% = 4
Greater than 60% = 5

Weed Species	Soil % Cover										Average	Cover Score
	1	2	3	4	5	6	7	8	9	10		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												

Bioindicators Analysis Sheet

Cover Score	Weed Species	Notes on soil properties and associations
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	11	
	12	
	13	
	14	

Bioindicators Species Guide

A guide to common non-crop plants and what they indicate about the soil conditions in which they are found, compiled from existing literature on plant bioindicators.

Latin name	Common name	Texture / Type	pH	Fertility	Structure	Moisture	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Crop Cover
Achillea millefolium	**Yarrow**			loss of OM[5]	erosion: tillage/over-grazing[5]				low K[1]	
Aethusa cynapium	**Fool's parsley**		neutral / alkaline[2,6] ☼	nutrient rich[2]			excess N[6]			
Alopecurus myosuroides	**Black-grass**	clay / heavy[2]		burial of OM[5]	plough pans / compaction / wet tillage[5]	poorly drained / water-logged[1,2] ☼				
Anisantha diandra	**Great brome**	sandy[2]								
Anisantha sterilis	**Barren brome**			lack of manure[5]	excess C[5]	well drained[2]	low N[5]	low P[5]		
Anthriscus sylvestris	**Cow parsley**		alkaline[2] / base-rich[5] ☼	mineral-isation of OM[5]		humid soils[2] / waterlogged[5] ☼				
Apera spica-venti	**Loose silky-bent**	light soils[2] / sandy / silty low in clay[7] ☼		balance of C and N[7]	wet tillage[4] / tillage when dry[7] ◈		balance of C and N[7]			low cover
Avena fatua	**Wild oat**	clay-lime-stone[5]	weakly acid to weakly al-kali[2] / high pH when compacted[5] ☼	highly fertile[2]	compac-tion[5]	moist[2]	excess N (when compacted and high pH)[5]		excess K (when compacted and high pH)[5]	
Bromus commutatus	**Meadow brome**	heavy soils[2]				moist[2]				
Capsella bursa-pastoris	**Shepherd's purse**	silty or sandy soils[5]	soils rich in bases[5]		compaction (soils rich in bases)[5]	avoids wet soils[2]		blockage of P by anaero-biosis[5]	blockage of K by anaero-biosis[5]	
Carex sp.	**Sedges**					wet / water-logged / poorly drained[1]				
Centaurea cyanus	**Cornflower**	sandy loams / chalky clays[2], dry, light, warm soils[4] ☼	blue - high lime[1], pink - acid[1]							
Cerastium fontanum	**Common mouse-ear**		acidic[2]	nutrient rich[2] / rich in OM[5] ☼		wetter soils[2]	rich in N[5]			
Chenopodium album	**Fat hen / White goosefoot / Lambs quarter**	loams / sandy[2]	high lime, alkaline soil[3]	high fertility / humus[1,2,3,4] / excess uncomposted animal OM[5] ☼☼☼☼	wet tillage[5]	moist[2]	surplus N at surface[4], high N[2] ☼	low P?	high K?	

Abbreviations

OM	Organic matter
CHC	Clay-humic complex
N	Nitrogen
P	Phosphorus
K	Potassium
C	Carbon

Key

level of source corroboration

☼	2 sources
☼☼	3 sources
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☼☼☼☼	5 sources
◈	source disagreement

Bioindicators Species Guide continued

Latin name	Common name	Texture / Type	pH	Fertility	Structure	Moisture	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Crop Cover
Cichorium intybus	**Chicory**	clay / heavy[1] / silty[5]	rich in bases[5]	high fertility / humus[1]	compaction (soils rich in bases) provoking anaerobic conditions[5]		excess N[5]	blockage of P due to elevated pH[5]	blockage of K due to elevated pH[5]	
Cirsium arvense	**Creeping thistle**	clay / heavy[1,4] ☼	rich in bases / high pH[5]	excess spreading of fertiliser or OM / saturation of CHCs[5]	smear layer[4]	wet soil / slightly damp[2,4] ☼	surplus N at depth[4]	blockage of P (excess fertiliser)[5]		thin crops[2]
Cirsium vulgare	**Spear thistle**			fertile[2]	congestion of OM[5]	well drained[2] / waterlogged (base rich soils)[5] ◈		blockage of P (humus deficiency and excess 'fossilised' OM)[5]		
Convolvulus arvensis	**Field bindweed**	sandy / light[1,3] deep, loose loams[2] ☼☼		nutrient rich[2]	compaction, hardpan or crusty surface[1,5] ☼	dry[2]	excess nitrates[5]			
Dactylis glomerata	**Cock's-foot**		neutral / alkaline[2]	fertile[2] / saturation of CAH with N / excess C[5]	compaction[5]		excess nitrates[5]			
Elytrigia repens	**Couch grass / Quack grass**	all soil types		high nutrient levels[4]	hardpan / crusty surface[1], smear layer / compaction[4], compaction of loamy soils w/high pH) / over tillage[5] ☼☼		excess nitrates[4]		excess potash[5]	gaps / sparse crops[4]
Equisetum arvense	**Field horsetail**	sand / light[1], alluvial soils[5] ◈	acid or low lime[4]		young alluvial / not yet structured / unstructured soils[5]	humid soil[3], smear layer[4] / water table[5] ☼☼				
Euphorbia helioscopia	**Sun spurge**				disturbed ground[5]					low cover[5]
Fallopia convovulvus	**Black-bindweed**		acid or low lime[2]	fertile[2]		moist[2]				
Fumaria officinalis	**Fumitory**	loam[2]	chalky / high lime[2] / rich in bases[5]	nutrient rich[2] / excess C[5] ☼		good water availability[2]			high K[1]	
Galeopsis tetrahit	**Common hemp-nettle**		rich in bases[5] / acid or low lime[2]	high organic matter[2] / excess C, low N and P[5] ☼		moist in summer[2]	low N[5]	low P[5]		
Galium aparine	**Cleavers / Goosegrass**	clay / loam[2]		high fertility / humus rich[2,4] ☼	compaction[3], smear layer[4] ☼	well watered[2]	surplus N at surface[4]			

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Geranium dissectum	**Cut-leaved crane's-bill**	loams[2]		nutrient rich[2] / excess manure[5] ☼	loose[2]		excess mineral N and nitrates[5]			
Geranium molle	**Dove's-foot crane's-bill**	sandy[2]	pH>5[2]	rich in humus / nutrients[2] / excess manure[5] ☼	loose[2] / low ability to retain nutrients and water[5]	moderately dry[2]	excess mineral N and nitrates[5]			
Hieracium sp.	**Hawkweeds**	fine, sandy or rocky soil, low in clay[5]	acid or low lime[1,3] / rich in bases[5,6] ☼	lack of N and P[5]	low ability to retain nutrients and water[5,6] ☼		low N[5]	low P[5]		
Holcus lanatus	**Yorkshire fog**		weakly acidic[2]	high fertility[2] / rich in OM[5] ☼	compaction	moist[2] balanced / precursor of waterlogging[5] ☼				
Juncus sp.	**Rushes**			excess C[5]		wet / water-logged / poorly drained[1,5] / gley[5] ☼				
Lamium amplexicaule	**Henbit dead-nettle**	sandy loam / light[2]		nutrient rich[2] / excess C (base rich soils)[5] ☼	erosion and leaching[5]	dry[2]	excess N (base rich soils)[5]			
Lamium purpureum	**Red dead-nettle**	sandy loam[2]		fertile, rich in nutrients, moderate OM[2]						
Legousia hybrida	**Venus's-looking-glass**		chalky soils[2] / rich in bases[6]	deficiency of humus and clay[6]			low N[2]			
Lolium multiflorum	**Italian rye-grass**	moderate[2]			compacted[7]	well-drained[2]	high N[2] / rich in N / excess nitrates[7] ☼			
Lolium perenne	**Perennial rye-grass**		pH 5-8[2]							
Lotus corniculatus	**Bird's-foot trefoil**			low fertility[3]						
Matricaria discoidea	**Pineapple weed**	sandy / loam[2]		nutrient rich[2]	compaction, hardpan or crusty surface[1]	damp soils[2]				
Medicago lupulina	**Black medic**					dry soil[3]	low N[1]			
Myosotis arvensis	**Field forget-me-not**		rich in bases[6]	excess C, sometimes excess manure[6]						

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Papaver rhoeas	**Common poppy**		sudden increases in pH[5]			good moisture[2] / contrasting: dry summer, wet winter[5] ◈				low cover[2]
Persicaria maculosa (Polygonum persicaria)	**Redshank / Lady's thumb**	sand / light[2]	acid or low lime[1], pH 5-7[2], acidic soil[3] ☼☼	high fertility / humus[2]	well aerated[2] / excess C / gley formation / cultivated or trampled when wet / anaerobic[5] ◈	wet / water-logged / poorly drained[1], humid soil[3] poorly drained[5] ☼☼				
Phleum pratense	**Timothy**	heavy[2]	balance of bases[6]	C/N and OM balance[6]		damp[2] / moisture balance[6] ◈				
Plantago lanceolata	**Ribwort plantain**			balance of OM / fertility / aerobic microbial activity[5]		moisture balance[5]				
Plantago media	**Hoary plantain**		richness in bases / pH >/=7.5[5]					blockage of P due to elevated pH[5]	blockage of K due to elevated pH[5]	
Plantago sp.	**Plantains**	clay / heavy[1,3]	acid or low lime[1]		compaction[3,5] ☼	wet/water-logged/poorly drained[3], anaerobiosis / hydric soils[5] ☼				
Poa annua	**Annual meadowgrass**			fertile soils[2,3]	compaction[3,5], erosion and leaching of soils with low retention capacity[5] ☼	humid soil[3]				
Poa trivialis	**Rough stalked meadowgrass**		pH>5[2]	excess of P & mineral nitrogen[5]	excess C[5]	moisture retentive[2] / waterlogged[5] ☼			excess P[5]	
Polygonum aviculare	**Common knotgrass / Prostrate knotweed**		acid or low lime[1,3] ☼	high fertility[2]	compaction[3,5] / erosion (summer)[5] ☼	well drained/ not water-logged[2]	excess nitrates/ nitrites (bare soil)[5]			low cover[2,5] ☼
Ranunculus repens	**Creeping buttercup**	clay / heavy[1,2] ☼	lime deficiency[4]		excess C/ compaction / cultivation of the soil when wet[5]	humid soil[3], wet / water-logged / poorly drained[1,5] ☼☼	surplus of N (nitrates) on the surface[4]			
Raphanus rapanistrum	**Runch / Wild radish**	sandy / loam[2]	acid or low lime[1], lime deficiency[4], excess lime[5] ◈	low fertility[1], high nutrient levels[2,4] ☼☼	compaction of soils rich in bases provoking anaerobic conditions[5]	extreme contrasts in moisture (dry then wet)[5]	surplus N at surface[4]	blockage of P due to anaerobic conditions[5]	blockage of K due to anaerobic conditions[5]	

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Rumex acetosa	**Common/ garden sorrel**		acid or low lime[1], slightly acidic[5] ☼		water and OM balance[5]	wet / water-logged / poorly drained[1], good moisture[5] ◈				
Rumex acetosella	**Sheep's sorrel**	sand / light[1], clay-lime-stone soils[5] ◈	acid or low lime[1,3] ☼	low fertility[3], absence, loss of humus due to a lack of manure (N and P)[5] ☼	low retention power[5]	humid soil[3]				
Rumex crispus	**Curled dock**	clay loams[2]	acidic soil[3], alkaline soils[5] ◈	nutrient rich[2], block-age of P and trace-ele-ments (due to anaerobio-sis)[5] ◈	compacted[2], excess C / hydric soils / anaerobic[5]	damp soils[2]		high P / blockage of P (due to anaerobic conditions)[5]	high K[5]	
Rumex obtusifolius	**Broad-leaved dock**	clay / heavy[1,2,3] ☼☼	acid or low lime[4,5] ☼	high fertility / humus rich[2], blockage of P and trace-el-ements (due to anaerobic conditions)[5]	excess C / hydric soils / anaerobic[5]	wet / water-logged / poorly drained[5]	high N[2], surplus nitrates in deeper soil layers[4] ☼	blockage of P (due to anaerobic conditions)[5]		
Senecio vulgaris	**Groundsel**	sandy loams[2]	pH>6[2] / base rich[5] ☼	high fertility / humus[1] / excess C[5]	loose[2] / low retention power / erosion[5] ☼		excess N (base rich soils)[5]			low cover[5]
Silene latifolia	**White campion / Cockle**	sand / light[1] / sandy / silicon / granite[5] ☼	rich in bases[5]	excess C, low N and P[5]		well-drained[2]	low N[5]	low P[5]		
Sinapsis arvensis	**Charlock / Wild mustard**		alkaline rich[2], over-applica-tion of lime / blockages due to rising pH[5] ☼	high organic matter[2]	well aerated[2] / compaction, leading to anaerobic conditions (in high pH soils)[5] ◈	dry often with thin topsoil[1], well drained		blockage of P[5]		
Sisymbrium officinale	**Hedge mustard**	sandy, loam, stony[2]	excess lime / rich in bases[5]	nutrient rich[2]	loose[2] / compaction by animals[5] ◈			blockage of P (anaerobi-osis)[5]		
Sonchus arvensis	**Perennial sow-thistle**	heavy, deep loams and clays[2]	high lime[1], base-rich[5] ☼		excess C / asphyxiation / compac-tion in wet weather[5]	wet / water-logged / poorly drained[1,5], damp to wet[2], (esp. in base-rich soils)[5] ☼☼	high in nitrates[2]			
Sonchus asper	**Prickly sow-thistle / Rough milkthistle**	loam / me-dium, loams / sandy / stony[2]		high fertility / humus[2] / excess C[5]		not too dry[2] / waterlogging[5] / anaerobic[5] ☼	N rich[2] / excess N[5] ☼		excess K[5]	

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Sonchus oleraceus	**Common/ smooth/ annual sow-thistle**	clay / heavy[1], loams / sandy / stony[2] ☼		nutrient rich[2] / excess C[5]		not too dry[2] / waterlogging[5] / anaerobic[5] ☼	N rich[2] / excess N[5] ☼		excess K[5]	
Spergula arvensis	**Corn spurry**	sand / light[1,2,3] ☼☼	acid or low lime[1,2,5], (low retention power in acid soils)[5] ☼☼	calcium deficiency[5]	loss of CHC binding power due to deficiency in stable humus / leaching, erosion[5]	excess irrigation[5]				erosion and leaching due to lack of soil cover[5]
Stellaria media	**Common chickweed**		neutral / alkaline	high fertility/humus[1,3], high nutrient levels[4], soil balance[5] ☼☼☼		watered but not water-logged[2]	surplus N at surface[4], N rich[2], release of nitrates[5] ☼☼			low crop cover, sparse crops[4]
Taraxacum sp.	**Dandelion**	clay / heavy[1,3] ☼	acid or low lime[1], pH>7[2], lime deficiency[4] ☼☼	high fertility/ humus[3]			surplus N on the surface and in deeper soil layers[4]			
Tussilago farfara	**Colt's foot**	clay / heavy[1]	acid or low lime[1] / rich in bases[5]		instability (rich in bases and clay) / moving soils[5]	wet / water-logged / poorly drained[1], humid soil[3] / pockets of water[5] ☼☼				
Urtica dioica	**Common nettle**	sand / light[3]	acid or low lime[1]	nutrient rich[2] / excess C[5] / change of state of iron in soil[5] ☼		hydric soil[5]				
Veronica hederifolia	**Ivy-leaved speedwell**			nutrient rich[2]	loose[2]					
Veronica persica	**Common field speedwell**	loams[2]	pH 6-8[2] / rich in bases[5] ◈	nutrient rich[2], rich in OM and N[5] ☼	compaction leading to anaerobic conditions[5]	dry often with thin topsoil, well drained[1]	rich in N[5]			
Vicia sativa	**Common vetch**	sandy[2]	rich in bases[5]		compaction (causing anaerobic conditions)[5]	dry[2]	low N[1]	blockage of P (due to anaerobic conditions)[5]	blockage of K (due to anaerobic conditions)[5]	
Viola arvensis	**Field pansy**	sand / light[3]	acid or low lime[1,3] ☼	lack of humus[7]	aerated[2]	watered but not water-logged[2]	low N[7]			

Abbreviations

OM	Organic matter
CHC	Clay-humic complex
N	Nitrogen
P	Phosphorus
K	Potassium
C	Carbon

Key

level of source corroboration

☼	2 sources
☼☼	3 sources
☼☼☼	4 sources
☼☼☼☼	5 sources
◈	source disagreement

Source

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