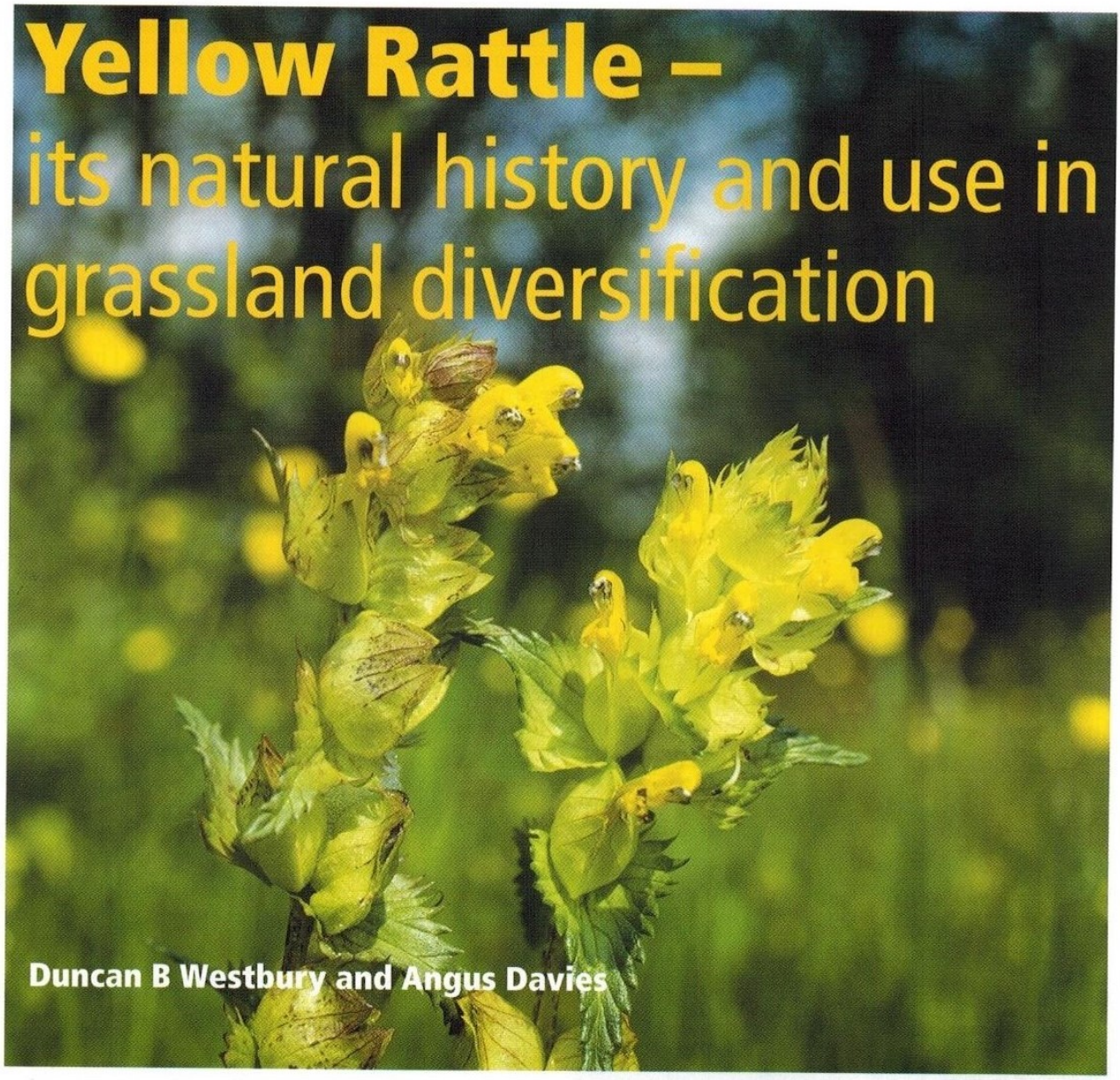
Yellow Rattle – its natural history and use in grassland diversification



Paul Sterry/Nature Photographers

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Over the last decade, there has been considerable interest in the conservation press concerning the value of Yellow Rattle *Rhinanthus minor* in aiding grassland restoration. The observation that the parasitism of Yellow Rattle can achieve significant reductions in the productivity of grasslands, and particularly of the dominant grasses (Davies *et al.* 1997), has highlighted this annual as a useful 'tool' in promoting species-rich swards. Understandably, for this very reason, Yellow Rattle has never been very popular amongst farmers.

The parasitising behaviour of Yellow Rattle was not widely known in the scientific world until the late 19th century. Whilst Holland (1808) found that, in Cheshire, Yellow Rattle was 'not in general liked by the farmer', it was not until 1847 that the French botanist Decaisne positively established that Yellow Rattle was a form of plant parasite that could reduce harvests. Certainly, at the dawn of intensive industrial agriculture in Britain, the presence of Yellow Rattle was noted as doing 'a great deal of harm' in grassland 'owing to the fact that it kills or seriously weakens the grass plant' (Bastin 1915). More prosaically, Long (1924) noted that farmers sometimes complained of butter tasting sour when produced from cows grazing on pastures containing the flower. Thus, the evidence was stacking up against this species as a permissible component of lowland grasslands, and for most of the 20th century 'scientific' management of meadows included the eradication of this plant (Davies & Davies 1997). Consequently, Yellow Rattle has vastly declined, along with its semi-natural grassland communities (Preston *et al.* 2002).

To the present, for most farmers, the idea of allowing a 'weed' that reduces grass yield to flourish in their meadows is anathema. Yet, under agri-environment schemes, farmers are financially encouraged to increase grassland biodiversity, which includes shifting from increasing *gross* productivity to redressing biodiversity declines. Consequently, views of Yellow Rattle are now changing, not only because it is facing rapid declines itself, but also because of its hemi-parasitic behaviour, which seems to enhance the diversification of species-poor grasslands. In this article, we attempt to summarise the natural history of Yellow Rattle and its value in grassland restoration.

Plant parasitism

It is estimated that 1% of all flowering plants are parasitic on other plants, which is equivalent to about 4,000 species (Press *et al.* 1998). Plant parasites are classified according to their point of attachment on the hosts (at either the roots or the shoots), and their degree of host dependence. Yellow Rattle is a *facultative* root hemiparasite, which means that it has the ability to gain nutrition both autotrophically, i.e. independent of a host, and heterotrophically, i.e. from a host. Through the formation of specialised root connections (haustoria), the parasite is able to obtain water and nutrients to satisfy its needs.

Greater Yellow Rattle. Paul Sterry/Nature Photographers

Recently, there have been major advances in taxonomy, using molecular phylogenetic classification. As a result, some plant families have been radically rejigged and, whereas the yellow rattles once belonged to the figwort family (Scrophulariaceae), they are now grouped within the broomrapes (Orobanchaceae) (Olmstead *et al.* 2001). This is a diverse group of plants, consisting of about 2,000 species in 78 genera. The most economically important taxa are the witchweeds *Striga* and broomrapes *Orobanche*, as infestations in cereal crops (maize, millet and sorghum) in semi-arid areas of sub-Saharan Africa can lead to dramatically reduced yields.

Description and distribution

Globally, the yellow rattles are found in the Northern Hemisphere, and, of the 45 species, two are native to the British Isles. Greater Yellow Rattle *Rhinanthus angustifolius* is listed as a Red Data Book species in the UK, and was once a weed of cereal crops, especially following grassland reversion. It was said that, if the seeds were ground up with cereal grain, this gave flour and bread a reddish or violet-brown colour and an unpleasant taste (Long 1924). However, with increased efficiency of seed-cleaning, and the species' susceptibility to herbicides, it is now in decline (Parker & Riches 1993) and is known only from about four localities in Surrey, Lincolnshire and Angus (Perring & Farrell 1983).

In contrast, ('Lesser') Yellow Rattle *Rhinanthus minor* has been recorded in all vice-counties in the British Isles (Fig. 1) and is widespread throughout most of Europe, although rare in the Mediterranean region. It is found also in North America and Asia. Yellow Rattle is highly variable, and also displays ecotypic variation. This, of course, further confuses the effort to distinguish between the six subspecies of *R. minor* found in the British Isles (Westbury 2004). Once ubiquitous in grassland throughout the UK, it is now mainly restricted to species-rich meadows, which have correspondingly also suffered dramatic losses in the past 60 years.

The genus name *Rhinanthus* is from the Greek *rhis,* meaning snout, and *anthos*, flower. The vernacular name is derived from the sound which the ripe seeds make in the dry capsules when the

Identification

- Stem erect to 500mm, often streaked or spotted black
- Leaves 20-30mm x 5-8mm, opposite and stalkless (sessile), coarse-toothed
- Flowers in spike-like raceme (flowering branch)
- Corolla yellow to brownish-yellow, two lipped; upper lip flattened, with two short violet teeth (1mm), lower lip 3-lobed, turned down away from upper lip
- Seed capsules flattened; seeds large and winged
- Greater Yellow Rattle distinguished by longer teeth on upper lip of corolla (c. 2mm), and corolla-tube curved upward

plant is shaken. A once familiar and evocative sound is the sibilant rustle of stands of Yellow Rattle in a flowery meadow at the height of summer.

Habitat

Yellow Rattle is found in a wide range of grassland habitats, but is absent where shade is heavy, hosts are sparse, and soils are below pH 5.0 (Grime *et al.* 1988). However, it is most typically, and abundantly, associated with hay-meadow communities of high floristic diversity (Grime *et al.* 1988). There are several reasons for this association. First, because Yellow Rattle normally manages to set seed before the traditional summer hay cut, it is effectively dispersed by the activities of *making* the hay, particularly turning and tedding. Secondly, Yellow Rattle responds positively to aftermath grazing, in particular the gaps created in the sward through trampling, which then aid the establishment and development of seedlings in the following spring (Smith *et al.* 1996).

Yellow Rattle is usually absent from productive swards, as it has a high light requirement and is vulnerable to competitive exclusion, especially at the seedling stage (ter Borg 1985). In addition, intensive grasslands are more likely to be cut for silage, a management which efficiently exterminates Yellow Rattle by preventing it from completing its annual life-cycle. Consequently, species-rich meadows are more hospitable owing to the lack of inorganic fertiliser applications and concomitant over-growth of dominant grasses.

The mosaic of plants within species-rich grassland also offers a greater range of parasitic opportunities, possibly explaining why populations of Yellow Rattle are often observed as transient patches, forming dense populations where there is sufficient host biomass to provide adequate opportunities, but not so high that the rattle is outcompeted for light (van Hulst *et al.* 1987). Under these optimal conditions, natural densities can exceed as many as 1,000 individuals in a square metre (Westbury 2004).

Figure 1 Although found in most 10km squares in the British Isles, Yellow Rattle is now mainly restricted to species-rich meadows and grasslands.

Yellow Rattle. Duncan Westbury

Yellow Rattle growing in species-rich grassland. Richard Revels

Life-cycle

Unlike most annuals, after dispersal, Yellow Rattle does not produce a persistent soil seed bank. The majority of seeds germinate in the following spring after seed dormancy is broken by winter chilling (stratification). Germination then takes place in February and March. The purpose of having large seeds is to provide ample energy for rapid root growth in order to be able speedily to forage for potential hosts. This is crucial for the young seedling as, without a host, it is a weakling amongst the burgeoning spring sward. Ironically, where Yellow Rattle densities are high, it will parasitise other Yellow Rattle plants, thus generating the interesting notion of a chain of interconnected plants, each leeching off the others. Typically, most plants reach flowering age from May through to July, fitting in their life-cycle with traditional hay-meadow management. However, it is not uncommon for some plants to flower in August, and well into September. Pollination is assisted by the fact that Yellow Rattle is hermaphrodite, and can be self-fertilised, or pollinated by insects, especially bees, which are attracted by the nectar secreted at the base of the ovary (Gibson 1986).

Yellow Rattle seed production is low, and dispersal of these seeds is also limited because of their large size and a lack of an active dispersal mechanism. However, they may be ejected from ripe seed capsules when the stiff stem is shaken by wind or a passing animal (Westbury 2004). Furthermore, the seeds are winged, making them suitable for wind dispersal (Gibson 1986; Grime *et al.* 1988), or even dispersal by water, as the seed is able to float for several months (Ridley 1930). Overall, though, unless aided by human activity such as hay-cutting or, more recently, deliberate conservation sowing, Yellow Rattle is a poor coloniser, and is restricted to places where it has been established for centuries, earning it its reputation as an indicator of old grassland (Rodwell 1992).

Yellow Rattle has a wide host range, which enables it to prosper amongst many different species assemblages and grassland habitats. In Britain, the list of potential hosts includes up to 50 species from a total of 18 plant families (Gibson & Watkinson 1989). However, certain host groups predominate, with legumes accounting for 11 species and the grasses for 16. Owing to the lack of cues needed for germination, host selection by Yellow Rattle may initially be a random process determined by relative host abundance. However, Yellow Rattle can infect several hosts simultaneously, and studies have shown that the average number of hosts can be up to four per plant (Gibson & Watkinson 1989).

Ecological application in grassland diversification

Yellow Rattle is now much in demand in conservation agriculture, and is a standard component of

wildflower-seed mixtures, and recommended for agri-environment schemes. It is precisely its ability to reduce grassland productivity – which previously made it a 'plant foe' of the farmer – that now makes it sought after as beneficial to the process of grassland restoration (Davies *et al.* 1997; Pywell *et al.* 2004). The impact of Yellow Rattle on grassland productivity is becoming widely documented. For example, Davies *et al.* (1997) showed that the presence of Yellow Rattle in experimental grasslands in North Yorkshire seemed to cause reductions of between 36%-73% in biomass production. Much of this loss was accounted for by reductions in grass biomass, which was 79% lower than in plots without the plant. Through reductions in productivity, the competition for space and nutrients between individuals and species is reduced, enabling a greater range and number of species to co-exist.

Most recently, Pywell *et al.* (2004) investigated the diversification of semi-improved, species-poor grassland in Oxfordshire by sowing Yellow Rattle two years prior to the introduction of additional wild flowers. In the second year after sowing the wild flowers, a significant relationship was established between Yellow Rattle frequency and gains in the establishment of wild flowers and in overall species richness. In a comparable study, Yellow Rattle was sown at a rate of 1,000 seeds per m^2 into a newly established Perennial Rye-grass *Lolium perenne* sward in conjunction with a standard meadow mix containing both forbs and desirable grasses. The presence of Yellow Rattle was also associated with a significant increase in diversity and the number of sown and unsown species (Westbury, Davies & Dunnett, unpublished). An increase in the number of species in the presence of the parasite is, of course, reliant on regular inflow of seed of desirable species, and it is most helpful if the grassland under restoration is close to an unimproved source. Without this assistance, as Mizianty (1975) observed, Yellow Rattle may well produce reductions of up to 25% in total grassland productivity, yet species number can remain unchanged.

Although the benefits of sowing Yellow Rattle have been widely demonstrated, it has been suggested that, in general, the impact of the parasite is too unpredictable for use as an effective conservation tool (Gibson 2000). The unpredictability is due mainly to variability in grassland composition and differences in productivity, but variation is also introduced through the quality of commercially bought seed and the levels of seed eaten after sowing, especially by voles (van Hulst *et al.* 1987).

Another concern over using Yellow Rattle for grassland diversification is that its presence may actually reduce plant diversity (Gibson & Watkinson 1992), and, moreover, anecdotal evidence suggests that it is poisonous to livestock, owing to the presence of the iridoid glycoside rhinanthin. It is not clear how harmful Yellow Rattle is to livestock, and most probably it is poisonous only after a prolonged period of exclusive consumption (Cooper & Johnson 1998). In fact, Morgan *et al.* (2005) showed that the inclusion of Yellow Rattle in forage can actually enhance digestion. In contrast to its possible toxicity, for humans the plant may have notable medicinal properties, being used for alleviating the symptoms of asthma and dry coughs, loosening catarrh and also as an eye-wash for various eye complaints (Johannsdottir 1992). It has also been used for the treatment of epilepsy and fits (Lacey 1993).

Reductions in plant diversity in association with Yellow Rattle may occur in several ways. For example, the vigour of desirable species such as Common Bird's-foot-trefoil *Lotus corniculatus*

Yellow Rattle in seed. Bob Gibbons

may be reduced, or species not susceptible to parasitism, such as Ribwort Plantain *Plantago lanceolata*, may be differentially promoted (Cameron & Seel 2003). Aggressive weed species also may be encouraged, and these in turn could outcompete desirable species (Joshi *et al.* 2000). Overall, predicting the outcome of introducing Yellow Rattle is likely to be more successful in grassland of low-moderate productivity that contains a predominance of species susceptible to parasitism.

Despite the apparent limitations of using Yellow Rattle, the indications are that it can be successfully used as a tool to facilitate the establishment and development of introduced species (Pywell *et al.* 2004; Westbury, Davies & Dunnett, unpublished). As the mortality of Yellow Rattle is greatest during seedling establishment and development, further investigation into techniques of reducing competitive exclusion during these stages is required if the scope of using Yellow Rattle is to be increased. For example, scarification (soil disturbance) in late autumn has been shown to increase establishment and survival to flowering (Westbury, Davies & Dunnett, unpublished). Persistent populations of Yellow Rattle have been established by using low sowing densities (Smith *et al.* 2000; Pywell *et al.* 2004), although establishment rates are generally greater with sowings of about 1,000 seeds per m^2, which equates to approximately 30kg per ha. However, persistent populations also may establish from sowing rates as low as 0.5-2.5kg per ha at the field scale (Pywell *et al.* 2004).

In conclusion, the efficacy of using Yellow Rattle to promote species diversity is more complex than it at first seems. Successful use relies on properly assessing site specifics, and, of course, not every site is suitable. However, despite some equivocal findings, the parasitic habit of this plant makes it a biological agent of positive change for species-rich grassland restoration.

References

Bastin, S L 1915 The warfare against weeds. *Journal of the Bath & West & Southern Counties Society* 10: 59-70

Cameron, D D, & Seel, W E 2003 Variable resistance to the grassland hemi-parasite *Rhinanthus minor*, and consequences for community composition. *Comp. Biochem. Physiol. A: Physiol*, 134, S158-S159

Cooper, M R, & Johnson, A W 1998 *Poisonous plants and fungi in Britain, animal and human poisoning*. The Stationery Office, London

Davies, A, & Davies, O 1997 English agriculturists' attitudes towards grassland vegetation, 1780-1914: an ecological perspective. *Land. Hist.* 18: 71-80

Davies, D M, Graves, J D, Elias, C O, & Williams, P J 1997 The impact of *Rhinanthus* spp. on sward productivity and composition: implications for the restoration of species-rich grasslands. *Biol. Conserv.* 82: 87-93

Decaisne, M J 1847 Sur le parasitisme des Rhinanthacées. *Ann. Sci. Nat.*, Sér 3, 8: 5-9

Gibson, C C 1986 *The population and community biology of* Rhinanthus minor *L.* PhD Thesis, The University of East Anglia, Norwich

Gibson, C C 2000 Use of hay rattle. *Enact* 8: 14

Gibson, C C, & Watkinson, A R 1989 The host range and selectivity of a parasitic plant: *Rhinanthus minor* L. *Oecologia* 78: 401-406

Gibson, C C, & Watkinson, A R 1992 The role of the hemiparasitic annual *Rhinanthus minor* in determining grassland community structure. *Oecologia* 89: 62-68

Grime, J P, Hodgson, J G, & Hunt, R 1988 *Comparative plant ecology – A functional approach to common British species*. Unwin-Hyman Ltd, London

Holland, H 1808 *A General View of the Agriculture of Cheshire*. London

Johannsdottir, A L 1992 *Islenskar Laekningajurtir*. Mal og Menning, Iceland

Joshi, J, Matthies, D, & Schmid, B 2000 Root hemiparasites and plant diversity in experimental grassland communities. *J. Ecol.* 88: 634-644

Lacey, L 1993 *Micmac Medicines – remedies and recollections*. Nimbus Publishing, Nova Scotia

Long, H C 1924 *Plants poisonous to livestock*. 2nd edn. Cambridge University Press, Cambridge

Mizianty, M 1975 Influence of *Rhinanthus serotinus* (Schonheit) Oborny on the productivity and floristic composition of the meadow plant association. *Fragm. Florist. Geobot.* 21: 491-505

Morgan, R, Westbury, D B, Kliem, K E, Hervas, G, & Mould, F L 2005 The degradation of *Rhinanthus minor* (yellow rattle) *in vitro*. *Proceedings of the British Society of Animal Science*, p 224. British Society of Animal Science, York

Olmstead, R G, DePamphilis, C W, Wolfe, A D, Young, N D, Elisons, W J, & Reeves, P A 2001 Disintegration of the Scrophulariaceae. *Am. J. Bot.* 88: 348-361

Parker, C, & Riches, C R 1993 *Parasitic weeds of the world: Biology and control*. CAB International, Wallingford, Oxford

Perring, F H, & Farrell, L 1983 *British Red Data Books: 1. Vascular Plants*, 2nd edn. Royal Society for Nature Conservation, Lincoln

Press, M C, Scholes, J D, & Watling, J R 1998 Parasitic plants: physiological and ecological interactions with their hosts. *The 39th symposium of the British Ecological Society* (eds M C Press, J D Scholes & M G Barker), pp 175-197. Blackwell Science, University of York

Preston, C D, Pearman, D A, & Dines, T D 2002 *New Atlas of the British & Irish Flora*. Oxford University Press, Oxford

Pywell, R F, Bullock, J M, Walker, K J, Coulson, S J, Gregory, S J, & Stevenson, M J 2004 Facilitating grassland diversification using the hemiparasitic plant *Rhinanthus minor*. *J. Appl. Ecol.* 41: 880-887

Ridley, H N 1930 *The dispersal of plants throughout the world*. L Reeve & Co, Ashford, Kent

Rodwell, J S 1992 *British Plant Communities Volume 3. Lowland Grassland and Montane Communities*. Cambridge University Press, Cambridge

Smith, R S, Corkhill, P, Shiel, R S, & Millward, D 1996 The conservation management of mesotrophic (meadow) grassland in Northern England. 2. Effects of grazing, cutting date, fertilizer and seed application on the vegetation of an agriculturally improved sward. *Grass Forage Sci.* 51: 292-305

Smith, R S, Shiel, R S, Millward, D, & Corkhill, P 2000 The interactive effects of management on the productivity and plant community structure of an upland meadow: an 8-year field trial. *J. Appl. Ecol.* 37: 1029-1043

ter Borg, S J 1985 *Population biology and habitat relations of some hemiparasitic Scrophulariaceae*. The population structure of vegetation (ed J White), pp 463-487. Dr W Junk Publishers, Dordrecht

van Hulst, R, Shipley, B, & Theriault, A 1987 Why is *Rhinanthus minor* (Scrophulariaceae) such a good invader? *Can. J. Botany* 65: 2373-2379

Westbury, D B 2004 *Rhinanthus minor* L. *J. Ecol.* 92: 906-927

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