The biology and non-chemical control of Barren Brome (Anisantha sterilis (L.) Nevski

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Barren Brome
(drake, haver-grass, sterile brome)
***Anisantha sterilis* (L.) Nevski**
(*Bromus sterilis* L.)

Occurrence

Barren brome is a winter, occasionally summer, annual, biennial or rarely perennial grass, native on rough and waste ground, in hedgerows, by roadsides, and a weed of arable land and gardens (Stace, 1997, Peters *et al.*, 1993). It is common throughout the UK (Clapham et al., 1987). Barren brome is abundant on sands and other dry, freely drained soils (Grime *et al.*, 1988). Prior to 1970 it was of little agricultural importance. Since the mid-1970s it has increased as a problem weed in cultivated fields being favoured by the growing of continuous winter cereals and the adoption of non-ploughing techniques (ADAS, 1981).

In a survey of grass weeds in southern England in 1981, barren brome was mainly confined to field margins and headlands and occurred infrequently in the field (Froud-Williams & Chancellor, 1982). One study suggested that there was limited spread up to 5 m into the field (Marshall, 1985). However, other studies found barren brome was distributed in the hedge bottoms, field margins and well into the field (Marshall, 1989). In a survey of UK cereal field margins recorded as part of Countryside 2000, barren brome was one of the most frequent species recorded (Firbank *et al.*, 2002). In a study of weeds in conventional cereals in central southern England in 1982, barren brome was found in 16 and 13% of winter wheat and winter barley respectively but not in spring barley (Chancellor & Froud-Williams, 1984). It also occurred in the headlands and hedges. A survey of the incidence of *Bromus* spp. as weeds of winter cereals in mainland Britain in 1989 found sterile brome to be the commonest brome species and that it accounted for 87% of sightings (Cussans *et al.*, 1994). The frequency appeared to have increased between 1982 and 1989. A study of changes in the weed flora of southern England between the 1960s and 1997 also suggests that barren brome has become more common (Marshall *et al.*, 2003). In cereals it can cause yield losses of 45% (Peters *et al.*, 1993).

Biology

Barren brome flowers from May to July. The flowers are mainly self-fertilised but some are cross-pollinated by the wind (Grime *et al.*, 1988). A mature plant may have up to 10 fertile tillers, each flower head having 10-12 spikelets each containing 4-10 seeds (ADAS, 1981). There may be 60 to 196 seeds per panicle and a well-spaced plant may produce 2,000 to 5,000 seeds (Burghardt & Froud-Williams, 1997). On average over 200 seeds are produced per plant and a high proportion are viable. This can result in seed numbers of 12,000 to 53,400 per m^2 (Peters *et al.*, 1993). Seeds become viable 3-7 days after anthesis. Seed matures rapidly on the plant once ripening begins and is shed from late-June to early-August. There may be some initial dormancy but the majority of seeds will germinate in contact with moist soil, especially if buried immediately. Ripe seeds are generally ready to germinate at once (Abram, 2004). Only seeds of a few populations exhibit innate dormancy (Peters *et al.*, 2000). Dry conditions will prevent germination. Temperatures below 0^oC will enforce seed dormancy. Sunlight will also inhibit germination and encourages the persistence of seeds left on the soil surface. There is great variation in the level of dormancy induced by light.

The inhibition of seed germination by light is transitory and only persists in the presence of light (Hilton, 1984). Seeds may vary in the level of inhibition due to the effect of environmental conditions during seed development. Some seeds are not inhibited at all by light in others germination is delayed for just a few weeks. Inhibition is lost after a period of dry storage. The lower the storage temperature, the longer the seed remains dormant. In some laboratory tests there was negligible germination in the light (Andersson *et al.,* 2002). In the dark there was some variation in germination levels between seed samples from different populations. However, in other Petri dish tests with seed maintained under high or low light intensity or in darkness, seed germinated completely in all conditions (Grime & Jarvis, 1976). Germination was uniformly high in alternating and constant temperatures in darkness and under a 'safe' green light (Grime *et al.,* 1981).

The main period of emergence is the autumn (Peters *et al*., 1993). Autumn rains usually encourage a flush of germination but if dormancy is enforced by drought or low temperature, seed may persist to the following spring. Seed numbers on the soil surface declined by 85% between July and late August but only 44% gave rise to seedlings (Froud-Williams, 1983). A further 10% gave rise to seedlings by late December and another 5% emerged between February and April. No viable seed remained after April. The seedlings that emerged in spring failed to flower before crop harvest. Seedlings need a cold period to vernalise them in order to flower. Spring emerging seedlings may not become vernalised. The time from emergence in autumn to flowering the following year is around 190 to 200 days (Burghardt & Froud-Williams, 1997).

In glasshouse studies, depth of sowing between 12 and 32 mm made little difference to final seedling numbers but the rate of emergence was slower at the greater depth (Okereke *et al.,* 1981). Seed sown outside in pots and boxes of soil emerged in large numbers over winter when left on the surface or sown 25 mm deep without further cultivation (Froud-Williams *et al*., 1984a). The result was the same with seed sown at 75 mm and cultivated in February or June. The optimum depth for seedling emergence was 0-70 mm and the maximum was 130 mm. No seedlings emerged from 150 mm. In other studies, seed sown on the soil surface or at 25 mm deep gave over 90% germination, seed sown at 150 mm germinated but seedlings did not emerge (Froud-Williams *et al.,* 1984b). Budd (1981) calculated the maximum depth of emergence to be 45 mm. Lintell Smith *et al.,* (1999), found that germination was greatest at depths of less than 50 mm and that emergence declined rapidly as depth increased beyond this. There was very little emergence from deeper than 100 mm.

Persistence and spread

Thompson *et al.* (1993) suggest that based on seed character, barren brome seed is likely to persist for less than 5 years. The majority of seed does not remain viable in soil for longer than a year and seed persistence is not generally a problem when considering control measures (ADAS, 1981). Seed of barren brome did not survive 5 months burial in soil (Budd, 1981). Seed mixed in a 75 mm layer of soil in cylinders sunk in the field all emerged in the first year and none persisted (Roberts, 1986). Seeds did not survive longer than 9 months on the soil surface (Froud-Williams, 1983). Most seeds will perish within a year but some can survive into a second year (Peters *et al*., 1993). The persistence of barren brome may be enhanced by enforced dormancy as a consequence of light, high temperature or moisture stress after shedding during the autumn (Froud-Williams, 1981).

There is a danger of seeds becoming introduced into fields from the headland especially where vegetation has been cleared allowing colonisation by annual weeds (Peters *et al*., 1993). Farming operations can carry seed from hedgerow plants progressively further into the field. The awned seed of barren brome becomes lodged in and on combines, for example. The drilling of contaminated crop seed may spread the weed further afield (ADAS, 1981). In the headland, 99% of barren brome seed was dispersed within 1 m of the parent plant (Rew *et al*., 1996). Most seed was disseminated away from the hedge and towards the crop. In the open field, seeds were observed up to 3.5 m from the source. Shed seeds are dispersed further by soil cultivation. A single pass with a rotary harrow has been found to move seeds up to 1.8 m but most seeds are moved around 0.25 m (Howard *et al.*, 1991). Secondary dispersal by working implements is generally greater downhill than uphill on sloping land (Steinmann & Klingebiel, 2004). After 1 year the average dispersal was 2.5 m uphill and 5.4 m downhill, the maximum dispersal values were 8.7 and 21.3 m respectively. Seed was moved up to 53 m in the forward direction during combine harvesting, ejected up to 7 m behind and scattered 1 m to either side (Rew *et al*., 1996). Seed on plants near the headland would normally be moved parallel to the headland during combining rather than into the centre of the field. Around 34% of barren brome seed was recovered in the harvested cereal grain (Howard *et al.*, 1991).

Although most seed is shed readily from late-June onwards, the basal seed of each spikelet may be retained on the plant (Pollard, 1982a). Panicles still containing seeds can be found in late-January. These seeds are slow to germinate when compared with shed seeds but have been shown to be viable. This may be a strategy for survival should the less dormant shed seed fail to establish.

Barren brome seed was found in horse-droppings and it occurred as an impurity in sainfoin seed (Salisbury, 1961). It has been found as a contaminant in 3% of barley and 2% of wheat seed samples. In a survey of grass seed contamination in 1960-61, barren brome seed was found in 1.8% of perennial ryegrass, 4.4% of Italian ryegrass, 1.3% of cocksfoot, 2.0% of meadow fescue, 6.0% of tall fescue and 3.3% of red fescue seed samples tested (Gooch, 1963). In farm saved seed, 6% of samples had one or more seeds present (Budd, 1981). In the period 1978-1981, it was found in 7-9% of wheat and 5-10% of barley seed samples tested at the Official Seed Testing Station (Tonkin, 1982). Contamination is higher in winter cereals, especially winter barley where the harvest coincides with peak shedding of barren brome seed (Froud-Williams, 1983; 1987). There is contamination of both straw and grain. The awned seed caryopsis is also carried on clothing and animal fur (Grime *et al.*, 1988).

Management
In a moist autumn there may be an opportunity to kill seedlings before drilling a crop (Peters *et al*., 1993). Other seedlings are destroyed by the cultivations associated with spring-sown crops. Shallow cultivations encourage germination if the soil is moist, and stale-seedbed techniques may be effective, but early sowing of cereals gives less time to deal with germinating weed seedlings between crops.

Only pure cereal seed should be sown and when barren brome is in the headland care should be taken not to spread it into the field. The inclusion of spring-sown crops can help to break the cycle and reduce infestations. Growing spring barley is likely to reduce the weed unless a dry autumn has prevented germination leaving the weed to emerge in the spring crop. Nitrogen levels in cereal crops had little effect on the population dynamics of barren brome (Lintell Smith *et al.*, 1999). However, it was said to have produced more seeds and been more competitive against winter wheat at high nitrogen levels (Lintell Smith *et al.*, 1991). Without some form of control, sterile brome populations can increase from one plant per m^2 to 786 per m^2 after 3 seasons. The population then reaches a plateau of 1,000 plants per m^2. Barren brome was more competitive in wheat than barley but increasing the crop seed rate had a greater effect in wheat than barley (Cousens *et al.*, 1985). In winter wheat, the density of barren brome was not affected by the presence of other weeds (McCloskey *et al.*, 1998).

Burial of barren brome seed prevents the development of dormancy due to sunlight. Results suggest that good control can be obtained by ploughing after harvest and burying seed below its depth of emergence, at least 10 cm deep, and if complete inversion is achieved (Budd, 1981). Seed shed in autumn and ploughed to 15 or 20 cm had only 4% of potential seedlings emerge in year 1 and none in subsequent years (Bowerman *et al*., 1993). Tine cultivations to around 10 cm depth resulted in 30% of potential seedlings emerging in year 1 and 0.1% of possible seedlings in year 2. Ploughing was more effective than minimum tillage in controlling barren brome in winter wheat (M^c^Closkey *et al.*, 1991). Under minimum tillage, densities of barren brome rapidly become very high (Lintell Smith *et al.*, 1999). Barren brome populations increased 10-fold under minimum tillage but decreased under systems that included ploughing (McCloskey *et al.*, 1998). In stubble, ploughing to 20 cm will eradicate barren brome, the seeds germinate but fail to emerge from this depth (Froud-Williams, 1983; 1987). Shallow cultivations to 5 cm stimulated germination and reduced the seed population by 34% and fewer seedlings emerged than on uncultivated stubbles.

Straw burning will destroy 97% of seeds on the soil surface but burning is no longer an option. Where the straw was burned after an autumn cereal, barren brome infestations in the following crop were less than 1 head per m^2 (Rule, 1987). Where the straw was baled or chopped and incorporated, head numbers were around 120 per m^2 in the next crop. Methods of straw disposal that involve minimal cultivations will normally result in a build up of barren brome (Turley *et al.*, 1996). Rotational ploughing, 1 year in 3, will usually keep the grass in check but if an infestation is allowed to reach an excessive level, annual ploughing may be required for several years running.

To prevent barren brome seeding, hay should be mown early and pastures cut at the beginning of June to (Morse & Palmer, 1925). In set-aside over a 3-year period, a sown cover of ryegrass or ryegrass/clover had a lower population of barren brome than natural regeneration (Boag *et al.*, 1994). With the natural cover, barren brome numbers increased both in the seedbank and as growing plants. Seed numbers were greater where the cover was cut once a year rather than twice. Under natural regeneration in set-aside in southern England, barren brome frequency increased in the vegetation cover between years 1 and 3 (Wilson, 1992).

In the headland, plants need to be cut down before the flower panicles emerge but plants can re-tiller after early cutting. Competition with sown species suppressed the growth of barren brome in headlands sown with grass or wildflower/grass mixtures in comparison with unsown headlands allowed to regenerate naturally (West *et al.*, 1997). In field margins sown with the perennial grasses *Festuca rubra, Poa trivialis* and *Holcus lanatus,* barren brome was the most aggressive species and dominated the other grasses if it emerged at the same time (Rew *et al.*, 1995). In an established sward, however, barren brome seed was unable to establish successfully. In headlands to which nitrogen fertilizer was applied, barren brome produced significantly more tillers, and seed production was positively correlated with increased nitrogen rate (Boatman *et al.*, 1994). However, fertilizer drift into the hedgebank from applications in the field had little effect on the growth of naturally occurring barren brome plants (Theaker *et al.*, 1995). In arable field hedgerows in May, barren brome growth was more extensive in areas cut in the autumn compared with those cut in April (West & Marshall, 2001). In the longer term, sowing a native perennial seed mix created a botanically diverse hedge base habitat that inhibited re-invasion by annual weeds. In a five-year study of weed spread, a boundary strip 2 m wide was sown with perennial ryegrass, mown twice a year, or was kept bare and rotovated twice a year (Milson *et al.*, 1994). In comparison with a cropped strip of winter wheat, the boundary strips delayed the spread of barren brome from the hedge into the field but did not prevent it. There was little difference between the boundary strip treatments.

An arithmetical model that calculates changes in a barren brome population under the influence of 16 factors has been produced based on results from field experiments (Pollard, 1982b). Another model has been developed that predicts the emergence of barren brome under a range of cultivation practices in the presence and absence of winter wheat (Firbank *et al.*, 1985). Regression models have been used to explain the variation in winter wheat yield when the crop was grown in additive mixtures with barren brome (Cousens *et al.,* 1988). Using the models it was possible to derive an economic weed control threshold for weed management depending on grain price and the cost of control measures. Zanin *et al.* (1993) determined the economic threshold for barren brome in winter wheat to be 40 plants per m^2 but its effect was much less in the absence of nitrogen.

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