The biology and non-chemical control of Ribwort Plantain (*Plantago lanceolata* L.)

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Ribwort plantain

(black jacks, black plantain, buckhorn plantain, cocks-and-hens, curl-doddy, ribgrass, kempseed, English plantain, long plantain, lancell, rat-tail, rib-wort, soldiers, tinker-tailor grass, windles)
***Plantago lanceolata* L.**

Occurrence

Ribwort plantain is a common perennial weed of arable fields and grassland (Long, 1938). It is native in grassy places on neutral or basic soils, and is abundant throughout the UK (Clapham et al., 1987; Stace, 1997). It is recorded up to 2,600 ft and remains have been found in prehistoric deposits (Salisbury, 1961). It is a common roadside plant (Grime *et al.*, 1988). Ribwort plantain is found in lawns but less frequently than greater plantain (Sagar & Harper, 1964). In early surveys of Bedfordshire, Hertfordshire and Norfolk it was distributed over all types of soil (Brenchley, 1911; 1913). In Wales ribwort plantain was used as a pioneer species for hill improvement. It is relatively drought resistant and is able to grow on dry sites such as embankments and chalk grassland (Tansley, 1949). Ribwort plantain has a preference for fine to medium textured soils, moderately rich in organic matter with a pH from 6.5 to 7.3 among vegetation that is mown or grazed (Dale *et al.*, 1965). It is characteristic of grassland on poor soil and is moderately resistant to trampling (Williams, 1976). Ribwort plantain is a very frequent birdseed alien (Hanson & Mason, 1985).

Ribwort plantain was especially associated with temporary grass or clover seed crops but was less frequent in cereals (Brenchley, 1920). In a survey of seeds in pasture soils in the Netherlands in 1966, while ribwort plantain was common in the sward it was not represented in the soil seedbank (Van Altena & Minderhoud, 1972).

A very variable species, ribwort plantain is frequently divided into many varieties and subspecies (Sagar & Harper, 1964). Ribwort plantain exhibits considerable genotypic and phenotypic variation (Grime *et al.*, 1988). Some of the differences are influenced by the habitat (Cavers *et al*., 1980).

Ribwort plantain has been used as food for sheep on poor land (Morse & Palmer, 1925). Sheep find it very palatable and it has been included in seed mixtures (Derrick *et al.*, 1993). While sheep are able to chew the leaves and crown down to the ground, cattle have more difficulty especially when the leaves are prostrate in shorter pasture. It is said to improve animal health and milk flavour (Cavers *et al*., 1980). It has been sown in a mixture with forage chicory and white clover as grazing for finishing lambs in New Zealand and in the UK. Ribwort plantain is high in calcium and sodium but lower in magnesium, potassium and phosphate (Wilman & Riley, 1993; Wilman & Derrick, 1994). It is relatively high in the trace elements cobalt and copper. The

fibrosity index is consistently low compared with ryegrass (Wilman *et al.*, 1997). Ribwort plantain has some medicinal uses (Barker, 2001).

Biology

Ribwort plantain generally flowers from May to August (Long, 1938), but flowering may begin in April and continue till the first frosts (Sagar & Harper, 1964). It requires long days to induce flowering (Cavers *et al.*, 1980). Flowering plants have a greater leaf dry weight than non-flowering ones suggesting that plants need to reach a minimum size to initiate flowering (Stewart & Thompson, 1982). A lower percentage of plants, 20% versus 87%, flowered in grassland than in a quarry site perhaps due to greater competition from the grass. Nevertheless, plants may flower in their first year (Grime *et al.*, 1988). Flowers are wind pollinated although insects visit to collect pollen. Ribwort plantain is self-sterile and entirely cross-fertilized (Warwick & Briggs, 1979). The average seed number per plant is 2,500 but a large plant may have 10,000 according to Salisbury (1961). Guyot *et al.* (1962) give the seed number per plant as 1,200 to 1,500. The average seed number per plant in ruderal situations is given as 4,060 (Pawlowski *et al.*, 1967). Pot experiments suggest that overall seed production is reduced as plant density increases (Palmblad, 1968). Seed numbers may be much less on poor soils with just 35 to 261 per plant (Cavers *et al*., 1980). The mean 1,000 seed weight varies from 1.17 to 1.85 g.

Seeds may mature 2-3 weeks after fertilization (Sagar & Harper, 1964). Some seeds are shed others remain on the plant (Cavers *et al*., 1980). Seeds can germinate in the autumn of production or in the following spring but there is intermittent germination through the year. The germination of fresh seed is not promoted by light (Wesson & Wareing, 1969). In Petri-dish tests with seed maintained under high or low light intensity or in darkness, seed germinated at 64% and 88% in high and low light respectively but only to 25% in the dark (Grime & Jarvis, 1976). However, in germination tests at 22^{o}C with seeds in darkness or continuous white light, there was 20% germination in the light and 56% in darkness (Tretyn *et al.*, 1988). When seeds were put to germinate under a leaf canopy or in diffuse white light there was 72% germination under the canopy and 70% in the diffuse light (Górski *et al.*, 1977). Germination increases after a period of dry storage (Grime *et al.*, 1988). In the laboratory, dry-stored seed germinated in the dark (Blom, 1978). In petri-dish tests with dry-stored seed imbibed in polyethylene glycol (PEG) solution to prevent germination, the seeds were kept in darkness or exposed to red and/or far-red light before being rinsed and put to germinate at 22^{o}C (Pons, 1991). Seeds germinated in the dark and exposure to red light resulted in only a small increase in germination. Far-red light reversed the effect of a short period of red light. Neither light nor temperature were particularly important factors in the germination of intact seeds according to Povilaitis (1956). Stratification at 1 to 7^{o}C for 6 weeks or longer improved the level of germination.

In the field, seeds will germinate in darkness especially with nitrate present and seedlings are able to establish in tall vegetation under certain conditions. However, germination was greater on bare soil rather than in vegetation cover on chalk grassland (Pons, 1989). This appeared to be related to lower nitrate levels where vegetation was present. The stimulation of dark germination by nitrate may act as a gap detection mechanism. Seeds seem to germinate and emerge better on soil that has been compressed by light trampling (Harper *et al.*, 1965). Seed sown in a 75 mm

layer of soil in cylinders sunk in the field and stirred periodically, emerged mostly from January to April with odd seedlings at other times Roberts & Boddrell, 1984). Seed mixed into the surface 25 mm of soil in boxes out of doors and stirred periodically, emerged from January to July (Chancellor, 1979). The main period of emergence was April to May. Seedlings emerged in autumn and spring in open areas of pasture where there had been overgrazing (Sagar & Harper, 1964). Seed germinates shallowly, usually at 5 mm depth (Hanf, 1970). In pot studies, seed germination was suppressed with increasing seed density (Palmblad, 1968). Seedling establishment was better on a rough soil surface.

A simple seed population dynamics diagram for ribwort plantain has been constructed based on data from a study where seed was scattered on plots that had been deep cultivate, surface cultivated or left as a closed sward cut to 75 mm (Mortimer, 1976). The seed being relatively small soon became incorporated in the surface seedbank. Invertebrate activity and greater openness at the soil surface increased the chance of seed burial. Around 10% of the seed produced seedlings and less than 1% of these reached maturity. Excluding invertebrates increased the number of seedlings that survived.

The seedlings develop adventitious roots and older plants develop a short thick rhizome that frequently produces buds (Sagar & Harper, 1964). Some roots are superficial, others penetrate deeply into the soil and confer good drought tolerance (Grime *et al.*, 1988). In close grazing the leaves are prostrate, in tall vegetation the leaves are erect. Plants are resistant to frost and overwinter as small rosettes with broader leaves than the linear lanceolate leaves borne in spring and summer (Cavers *et al*., 1980). The rosettes start into growth in spring.

Persistence and Spread

Thompson *et al.* (1993) suggest that based on the seed characters, ribwort plantain seed should persist longer than 5 years. Seed longevity in dry storage and in soil is 10 to 12 years (Guyot *et al.*, 1962). The seeds gave 10% germination after 10 years soil burial but the seeds in dry storage were all dead after 10 years (Brenchley, 1918). In Duvel's burial experiment, seed buried at 20, 55 and 105 cm gave 21% germination in year 1, then 34, 51 and 6% respectively in year 3, 4,3 and 4% in year 10 and less than 2% in year 16 (Toole, 1946; Goss, 1924). Seed buried in mineral soil at 13, 26 or 39 cm depth and left undisturbed retained 72, 21 and 35% viability respectively after 4 years but was not viable after 20 years (Lewis, 1973). Seed buried in a peat soil at 26 cm was not viable after just 1 year. Seed stored under granary conditions had 85% viability after 1 year but was not viable after 20 years. In studies with seeds buried at 2.5, 10.0 or 17.8 cm deep in soils with different water tables, seeds of ribwort plantain did not deteriorate as quickly in wetter soils (Lewis, 1961). Dry-stored seed gave 29% germination after 5 years (Kjaer, 1940). Seed buried in soil for the same period also had 29% viability. The estimated persistence in soil is 50-60 years (Sagar & Harper, 1964) but the seed did not persist in cultivated soil (Roberts & Boddrell, 1984). Most seeds germinate or die within 12 months but buried seeds can persist for up to 16 years (Cavers *et al*., 1980). The annual percent decline of seeds in cultivated soil was 60% (Popay *et al*., 1994). Seed submerged in water gave 18% germination after 4 years (Comes *et al.*, 1978).

In grassland studies, population numbers remained relatively constant but on close inspection there was a regular turnover of individuals (Sagar, 1970). Seedling mortality was high but some established to become mature plants that then replaced individuals that had disappeared. Seedling establishment was greater in bare ground but losses were still high. Fewer than 11% of seeds became seedlings and many of these perished. Plants in permanent grassland had a half-life of 13.5 months (Sarukhán & Harper, 1973). In pot studies it was found that the leachate from ribwort plantain plants inhibited the growth of other ribwort plantain plants (Newman & Rovira, 1975).

Ribwort plantain may behave as a biennial or even an annual but is a true perennial with a thick short rhizome. Plants may persist for 12 years or may flower and die as annuals (Cavers et al., 1980). Ribwort plantain can regenerate vegetatively from buds on the stem or rhizome (Grime *et al.*, 1988). Connections between ramets in a clump of rosettes may break up to produce individual plants. Root pieces will regenerate in pots but this has not been recorded much in the field (Sagar & Harper, 1964).

There is no active seed dispersal mechanism but the seed coats become mucilaginous and sticky when wet (Sagar & Harper, 1964, Young & Evans, 1973). The seeds may adhere to animals (Weber, 2003). Apparently viable seed has been found in samples of cow manure (Pleasant & Schlather, 1994). More than half the seeds eaten by cattle were still viable after passage through the digestive system (Sagar & Harper, 1964). Seeds have been found in cattle droppings and in the droppings of sparrows, pigeons, bullfinches and greenfinches (Salisbury, 1961; Cavers *et al*., 1980). Germination is enhanced by passage through birds. Seedlings have been raised from the excreta of various birds. Seeds are ingested by earthworms and pass out unharmed in worm cast soil (Cavers *et al*., 1980).

Ribwort plantain seeds may occur as an impurity in clover and grass seed (Long, 1938). In perennial ryegrass seed tested in 1960-61, ribwort plantain seed was a contaminant in 1.8% of samples of English origin and 25.6% of Irish seeds (Gooch, 1963). In clover and grass seed samples tested in Denmark for the period 1966-69, 1955-57, 1939 and 1927-28, ribwort seed was a contaminant in 2.1, 28.0, 36.9 and 42.6% of samples respectively (Olesen & Jensen, 1969).

Management

Ribwort plantain may be kept in check by good cultivation, well-cleaned root crops and the use of pure seed (Morse & Palmer, 1925).

Avoid sowing plantains as seed contaminants in grass seed. In grassland, undergrazing favoured ribwort plantain but the weed also did well in managed pasture where stocking levels were adjusted to the grazing available (Kydd, 1964). However, in some grazing studies, ribwort plantain was unaffected by different strategies of tight and lenient grazing on pasture (NERC, 2006). Ribwort plantain is reduced more by grazing than by mowing and is less resistant to trampling than greater plantain (Sagar & Harper, 1964). In roadside verges, ribwort plantain frequency increases with cutting frequency but is particularly favoured by cutting twice a year (Parr & Way, 1984; 1988).

In greenhouse tests in the USA, corn gluten meal (CGM) applied as surface and incorporated treatments to soil sown with ribwort plantain seed has been shown to reduce plant development (Bingaman & Christians, 1995). Application rates of 324, 649 and 973g per m^2 reduced ribwort plantain survival by 80, 95 and 96% respectively. Shoot and root length were reduced by up to 90 and 100% respectively. Corn gluten hydrolysate (CGH) a water soluble derivative of CGM applied as a powder at 1, 2, 4, and 8 g/dm^2 to pots sown with seeds of ribwort plantain reduced seedling survival by 75, 85, 100 and 100% respectively (Liu & Christians, 1997). Both root and shoot development of survivors was severely reduced by treatment.

Ribwort plantain is attacked by a range of insects and is an alternate host of several aphid species. The flower and seed heads are often predated (Grime *et al.*, 1988). The leaves are not eaten by slugs or snails. Ribwort plantain is grazed by rabbits and is favoured by a reduction in the rabbit population (Thomas, 1963).

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