The biology and non-chemical control of Knotgrass (*Polygonum aviculare* L.)

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Knotgrass

(armstrong, black strap, bloodwort, centinode, crab-grass, cow grass, hogweed, iron-grass, nine joints, ninety knot, pigweed, prostrate knotweed, red-legs, red robin, redweed, stone-weed, surface twitch, wire-grass, wireweed)
***Polygonum aviculare* L.**
(*P. heterophyllum* Lindman)

Occurrence

Knotgrass is a procumbent summer annual weed found on all sorts of open ground. It is common throughout Britain (Stace, 1997). Knotgrass is native on disturbed ground, arable land, roadsides, seashores, gardens and waste places (Lousley & Kent, 1981). It occurs on tramped land around habitations (Frankton & Mulligan, 1970). It has been recorded up to 1,800 ft in Britain (Salisbury, 1961). It is a plant of disturbed and trampled habitats, in pasture it is restricted to gateways (Grime *et al.*, 1988). In urban situations it occurs in less trampled paved areas (Benvenuti, 2004). Knotgrass is frequently troublesome among cereal and root crops and is often abundant on light sandy soils, and on soils manured by sheep (Long, 1938). In early surveys of Bedfordshire, Hertfordshire and Norfolk, knotgrass was very common on most soils but rare on chalk. It was characteristic of clay and chiefly associated with light and sandy loams (Brenchley, 1911; 1913). Knotgrass was said to occur on soils deficient in lime and that liming was an aid to its reduction (Fenton, 1931). There is evidence that it was a pioneer species in the late-glacial period in Britain (Holzner & Immonen, 1982). Knotgrass appears to have some salt tolerance (Grime *et al.*, 1988). Knotgrass can occur as a birdseed alien (Hanson & Mason, 1985).

Knotgrass is a common garden weed (Copson & Roberts, 1991). Knotgrass was thought to be discouraged by competitive crops like cereals (Brenchley, 1920). Thurston (1976), found knotgrass was not important in winter wheat but was widespread in spring beans. In a survey of weeds in conventional cereals in central southern England in 1982, knotgrass was found in 6, 5 and 4% of winter wheat, winter barley and spring barley respectively (Chancellor & Froud-Williams, 1984). In a study of seedbanks in some arable soils in the English midlands sampled in 1972-3, knotgrass was recorded in 88% of the fields sampled in Oxfordshire and 97% of those in Warwickshire (Roberts & Chancellor, 1986). Knotgrass was one of the most frequent dicotyledonous weeds emerging in cereals in NE Scotland in 1973 and was still frequent in 1985 (Simpson & Carnegie, 1989). In Morayshire it was the most frequent weed. Knotgrass seed was found in 41% of arable soils in a survey in Scotland in 1972-1978 (Warwick, 1984). It accounted for 7% of the seeds in the soil seedbanks. It was also one of the most abundant weeds in a seedbank survey in swede-turnip fields in Scotland in 1982 (Lawson *et al.*, 1982). It was found in 90% of fields sampled. Knotgrass was one of the main weed species present in conventional sugar beet crops surveyed in East Anglia in autumn 1998 (Lainsbury *et al.*, 1999). It was common in the field margins too. In a study of field margins, knotgrass was not found in hedge bottoms and seedling numbers increased with distance into the field (Marshall, 1985). Knotgrass remained widespread in the period from 1978 to 1990 in

the UK despite increased herbicide use (Firbank, 1999). In a seedbank survey of arable fields in France in 1983-85, knotgrass was common in the seedbank and relatively more frequent in the standing vegetation (Barralis & Chadoeuf, 1987). In a survey of seeds in pasture soils in the Netherlands in 1966, knotgrass was common in the sward and in the soil seedbank (Van Altena & Minderhoud, 1972). In a 3-year set-aside, knotgrass frequency increased with increasing distance from the field edge (Rew *et al.*, 1992).

The *P. aviculare* group includes four 'species' which are themselves very variable, all are native (Clapham *et al.*, 1987). *Polygonum aviculare* L. is found on roadsides, waste places and the coast, *P. boreale* (Lange) Small is recorded in N. Scotland, *P. rurivagum* Jordan ex Boreau occurs on arable fields on chalky soil, *P. arenastrum* Boreau (Small-leaved knotgrass) is common throughout the UK often in dry places. There is considerable overlap in appearance between the different types (Grime *et al.*, 1988).

The fibrous roots were used as a quinine substitute in Africa (Mitich, 1998). The seeds are emetic and cathartic. Knotgrass has been found to be important in the diet of skylarks and linnets (Lainsbury *et al.*, 1999).

Knotgrass may carry several nematode species that can infect some important crops (Thurston, 1970). The stem nematode, *Ditylenchus dipsaci*, can infest it (Franklin, 1970).

Biology

Knotgrass flowers occurs from July to November according to Lousley & Kent (1981), and May to October according to Long (1938). The flowers are probably self-pollinated (Grime *et al.*, 1988). Seed is produced in abundance from July onwards and knotgrass can be found in fruit for 4 months of the year (Salisbury, 1962). Seed numbers per plant have been given as 160, 4,600 and 6,380 (Stevens, 1957). Guyot *et al.* (1962) give seed numbers per plant as 125 to 200. The average seed number per plant in ruderal situations is 4,093 (Pawlowski *et al.*, 1967). In cereals and winter rape the average seed number per plant ranged from 4 to 11 and in root crops from 633 to 755 (Pawlowski, 1966). The 1,000 seed weights presented by various authors range from 0.675 to 2.700g (Stevens, 1932). Seed rain from plants that emerged following cultivation in early April extended from August to November (Leguizamón & Roberts, 1982). Seed numbers in soil to a depth of 100 mm increased from 180 initially to a final 1,300 seeds per m^2.

Seeds were dormant when ripe and for 60 days after maturing (Justice, 1941). Scarification of seed, low winter temperature and chilling at 2-4^oC for 8 weeks increased germination levels. Germination capacity steadily increased during 5 months moist storage at 4^oC (Henson, 1969). The level of germination increased from 2 to 44% following a 3-month period of moist storage at 5^oC (Grime *et al.*, 1981). Seeds kept outdoors in moist soil overwinter, exhumed in darkness and put to germinate in 12 hours per day light, in darkness following a 5 second light flash or in complete darkness gave 61%, 52% and 33% germination respectively (Andersson *et al.*, 1997). Buried seeds removed from the field at intervals through the year and tested for germination first became able to germinate when lifted in December (Courtney, 1968). The ability to germinate increased in seeds lifted in January and

February but began to decline in April and ceased by June. It suggests that dormancy is overcome by low winter temperatures and re-imposed when temperatures increase in late spring. Just a short period at a high temperature may be sufficient to induce dormancy. Dormancy develops rapidly in seed at or near the soil surface. Seedling emergence in the field occurs from late February, when the soil begins to warm up, until May. Seedlings that emerge later, following soil disturbance, probably come from deeper in the soil where temperatures have not risen high enough to induce dormancy. With alternating temperatures, increasing the amplitude of temperature fluctuations increased germination in the dark up to an amplitude of 25^{o}C and in the light up to an amplitude of 20^{o}C (Thompson & Whatley, 1983).

The annual dormancy cycle of buried seeds exposed to natural conditions in field studies in the USA was examined by exhuming seeds at monthly intervals over a 3-year period (Baskin & Baskin, 1990). Seeds become non-dormant during autumn and winter. The seeds remain non-dormant in spring but the germination requirements become more specific until the majority of seeds are dormant.

Seed sown in pans of field soil emerged chiefly in winter and early spring (Brenchley & Warington, 1930). Field emergence in plots cultivated at monthly, 3 monthly or yearly intervals or not at all extended from March to June (Chancellor, 1964b). The least number of seedlings emerged from the uncultivated plots. Seed mixed into a 150 mm layer of soil in cylinders sunk in the field and stirred periodically, emerged from February to June (Roberts & Feast, 1970). The majority of seedlings emerged from 1st January to 31st March (Horne, 1953). In the field, cultivations in March and April gave rise to seedling numbers that represented relatively high percentages (14%) of the viable seeds present in the soil seedbank (Roberts & Ricketts, 1979). Fewer seedlings emerged following cultivation in May and hardly any or none in response to subsequent cultivations. Seedling emergence in Scotland recorded in field plots dug at monthly intervals began in April and continued through until July with peaks in April/June (Lawson *et al.*, 1974).

Seed sown at different depths with and without cultivation in pots and boxes of soil out in the field emerged mainly in spring when left on the soil surface or sown 25 mm deep without cultivation or at 75 mm and cultivated in February (Froud-Williams *et al.*, 1984). When sown at 75 mm and cultivated in June there was little emergence. In a second experiment, seedlings emerged in spring when seed was surface sown or sown at 50 mm and cultivated or not. The optimum depth of emergence was 0-20 mm and the maximum was 60 mm. In the field, 94-97% of seedlings emerged from the surface 30 mm of a sandy soil with the odd seedling from down to 50 mm (Chancellor, 1964a). In a sandy loam soil, field seedlings emerged from the top 60 mm of soil with most from the top 30 mm (Unpublished information). Seedling emergence declines with increasing depth of seed burial (Grundy *et al.*, 1996). When seeds were buried in discrete layers at 6, 19, 32, 57, 108 and 210 mm most seedlings emerged from the top 50 mm of soil. When the seeds were distributed through the soil profile down to the different depths, seedling emergence was spread further down the soil.

Knotgrass has a tough wiry taproot and plants can regenerate if the top is cut off during the growing season (Salisbury, 1961).

Persistence and Spread

Thompson *et al.* (1993) suggest that based on seed characters, knotgrass seed should persist for longer than 5 years in soil. Seeds are said to remain dormant in soil for 60 years (Salisbury, 1961). Seed longevity in dry storage and in soil was more than 4 years according to Guyot *et al.* (1962). Seed recovered from excavations and dated at 20 years were found to germinate (Ødum, 1974). Seeds buried in soil gave 55% germination after 20 years and 4% after 50 years (Crocker, 1938). The life span of seeds in dry storage was less than 15 years. Seed buried in soil in subarctic conditions had 13, 3 and 1% viability after 2.7, 6.7 and 9.7 years respectively (Conn & Deck, 1995).

Seeds mixed with soil and left undisturbed had declined by 61% after 6 years but in cultivated soil the decline was 92% (Roberts & Feast, 1973). The decline of seeds broadcast onto the soil surface and then ploughed in was followed over a 6 year period of cropping with winter or spring wheat. The experiment was made on a clay and on a silty loam soil. Every effort was made to prevent further seed return to the soil. Knotgrass had a mean annual decline rate of 23% and an estimated time to 95% decline of 9-20 years (Lutman et al., 2002). Seedbank decline was also studied in a succession of autumn-sown crops (winter wheat & winter OSR) in fields ploughed annually for 3-4 years with seed return prevented (Lawson *et al.*, 1993). Exponential curves indicated a time to 99% decline of 5 years and a mean decline per year of 60%.

In a study of post-dispersal seed predation in spring barley the main predators were invertebrates, birds were not important predators at this time (Mauchline *et al.*, 2005). Seed predation was greatest early in the year when up to 90% of presented seeds were taken. Losses gradually declined over the summer and by late September few seeds were taken.

Seeds are dispersed by birds, mammals and by water (Weber, 2003). Seed has been recovered from irrigation water in the USA (Kelley & Bruns, 1975; Wilson, 1980). Seed submerged in water gave 46% germination after 9 months, 21% after 3 years and 1% at 5 years (Comes *et al.*, 1978). Seed has been found in cattle and horse droppings and seedlings have been raised from bird excreta (Salisbury, 1961). Apparently viable seeds were found in samples of cow manure (Pleasant & Schlather, 1994). Seed that had passed through a cow gave 35% germination (Horne, 1953).

In cereal seed samples tested in 1961-68 knotgrass was one of the most frequent contaminants being found in up to 8% of rye, 11% of oats, 12% of barley and 9% of wheat samples tested (Tonkin, 1968). In the period 1978-1981, it was found in 4-17% of wheat and 15-20% of barley seed samples tested (Tonkin, 1982). In cereal seed samples tested in 1986-97, knotgrass was found as a contaminant in up to 2.7% of oat, 1.6% of barley and 1.3% of wheat samples tested (Don, 1997). In a survey of weed seed contamination in cereal seed in drills ready for sowing on farm in spring 1970, knotgrass was found in 18% of samples (Tonkin & Phillipson, 1973). Most of this was home saved seed. In clover and grass seed samples tested in Denmark for the period 1966-69, 1955-57, 1939 and 1927-28, knotgrass seed was a contaminant in 3.4, 11.7, 7.2 and 11.6% of samples respectively (Olesen & Jensen, 1969). In a survey of seed contamination in 1960-61, knotgrass seed was found in 3-4% of vegetable brassica, 4% of onion, 7% of leek, 2% of celery, 10% of carrot and 4% of lettuce seed samples tested (Gooch, 1963).

Management

Seedlings should be hoed off or hand-weeded and mature plants should be removed before flowering (Weber, 2003). Seedbed preparations and hoeing in spring kill many seedlings (Morse & Palmer, 1925). Unless seeding is prevented, eradication is impossible (Long, 1938). The adoption of a short rotation, growing more root or hoed crops may prevent seeding and aid control. Two fallow crops in succession will help particularly where surface cultivations in spring encourage germination for destruction by harrows.

A root crop such as kale, to be folded off by sheep, will almost exterminate the weed. Initially the seedbed preparations and early hoeing in spring kill the weed seedlings. Later the growing kale shades out the weed and, in folding, the close treading of the sheep prevents further weed growth before the land is ploughed. In grassland, trampling by livestock leads to soil compaction that benefits knotgrass (Wells, 1985).

In a comparison of different tillage regimes in winter cereals, knotgrass was favoured by deep cultivations and ploughing and discouraged by shallow cultivations (Pollard & Cussans, 1981). In wheat crops, 2 or 3 severe harrowings when the surface is crumbly will reduce the weed.

Seed numbers in soil were reduced by 75% after fallowing for 1 year and by 95% if this was extended for a further year (Brenchley & Warington, 1933). The land was ploughed, disked and harrowed during this time. Seed numbers were similarly reduced by cropping with winter wheat for the same period, provided good weed control was maintained. The weed has a very limited period of emergence that makes it more readily prevented from seeding. Fallowing every 5th year over a 15 year period reduced weed seed numbers in soil by over 90% after the first fallowing and maintained this level of seed numbers at each of the 2 subsequent fallow years (Brenchley & Warington, 1936). In the intervening cropped years there was little recovery in seed numbers.

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