The biology and non-chemical control of Shepherd's Purse (*Capsella bursa-pastoris* L.)

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Shepherd's purse

(bad man's oatmeal. blind-weed, case-weed, cocowort, lady's purse, mother's heart, pepper-and-salt, pick-pocket, shepherd's bag, ward-seed, witches' pouches)

***Capsella bursa-pastoris* L.**

(*C. simplex*, *Bursa bursa-pastoris, Thlaspi pursa-pastoris*)

Occurrence

A native summer or winter annual to biennial weed common everywhere on cultivated land, waysides and waste places (Clapham *et al.*, 1987; Stace, 1997; Rich, 1991). It is widely distributed and grows on most soils, sometimes in large numbers (Long, 1938). Shepherd's purse is a common garden weed (Copson & Roberts, 1991). It has been called the second commonest flowering plant on Earth (Hurka & Benneweg, 1979). In early surveys of Bedfordshire, Norfolk and Hertfordshire, shepherd's purse was common and universally distributed on all soils but was probably most frequent on light and sandy land (Brenchley 1911; 1913). It is infrequent on grassland except in bare areas and is absent from wetland (Grime *et al.*, 1988). Shepherd's purse is adapted to a wide climate range and will grow in sun or shade (Mitich, 2001). Shepherd's purse has been recorded up to 1,750 ft in the UK (Salisbury, 1961).

In arable fields it was commonly associated with spring barley (Brenchley & Warington, 1930). However, it was found as often among one type of arable crop as another (Brenchley, 1920). In a study of seedbanks in some arable soils in the English midlands sampled in 1972-3, shepherd's purse was recorded in 56% of the fields sampled in Oxfordshire and 59% of those in Warwickshire (Roberts & Chancellor, 1986). Seeds of shepherd's purse were not found in a survey of arable soils in Scotland in 1972-1978 (Warwick, 1984). However, it was a common weed in a seedbank survey in swede turnip fields in Scotland in 1982 (Lawson *et al.*, 198-). It was found in 55% of fields sampled, often in high numbers. Shepherd's purse was relatively common in a survey of weeds in spring cereals in NE Scotland in 1985 (Simpson & Carnegie, 1989). A study of changes in the weed flora of southern England between the 1960s and 1997 suggested that shepherd's purse had become more common (Marshall *et al.*, 2003). In seedbank studies in arable fields in France, shepherd's purse was well represented in the seedbank and in the emerged vegetation (Barralis & Chadoeuf, 1987). In trials in Denmark from 1969-1988, shepherd's purse was common in autumn-sown arable crops and in spring-sown crops too (Jensen, 1991). In a survey of seeds in pasture soils in the Netherlands in 1966, while shepherd's-purse was uncommon in the sward it was well represented in the soil seedbank (Van Altena & Minderhoud, 1972).

Self-pollination has resulted in the development of local strains of shepherd's purse that differ in leaf shape, fruit shape and seed number (Salisbury, 1961). The level of variability in populations depends on the amount of soil disturbance (Bosbach *et al.*, 1982). In frequently disturbed soils there are a greater number of genotypes. In a less disturbed habitat the population will be more stable and less variable. This applies both to the above ground population and eventually to the seedbank too. Tricotyledonous seedlings occur occasionally, 1 in 5,500 seedlings (Brenchley & Warington, 1936). Shepherd's purse is a very frequent birdseed alien (Hanson & Mason, 1985).

Shepherd's purse is a host of various insect pests and the pathogen white rust (*Cystopus candicus*) (Salisbury, 1962). It can also be a source of various nematodes and viruses that could potentially infect economically important crop species (Thurston, 1970; Heathcote, 1970).

Shepherd's purse has many medicinal and therapeutic uses (Barker, 2001). It has long been regarded as a medicinal plant to treat various ailments both internally and externally. In Britain it has been used to control scour in cattle and diarrhoea in humans (Mitich, 2001). The plant may have cancer-preventing properties. Young plants can be used as a potherb and the leaves are eaten raw in salad.

Biology

Flowering and fruiting occur throughout the year (Clapham *et al*., 1987; Stace, 1997; Rich, 1991; Salisbury, 1962). Plants have been found in flower in early January. Flowers are most abundant from May to October and are mainly self-pollinated (Grime *et al.*, 1988). Most seed is set from June to October. The average number of seeds per plant has been quoted at 38,500 (Stevens, 1932) 3,500 to 4,000 (Salisbury, 1961), 4,500 (Salisbury, 1962), 3,700 and 21,000 (Stevens, 1957), 2,000 to 40,000 (Guyot *et al.*, 1962) and 5,000 to 90,000 (Hurka & Haase, 1982). The average seed number per plant in ruderal situations is given as 12,090 (Pawlowski *et al.*, 1967). In spring cereals the average seed number per plant ranged from 1,012 to 1,262, in winter cereals from 1,987 to 2,424 and in root crops from 7,443 to 8,360 (Pawlowski, 1966). The average seed number per plant in red clover was 2,616 and in winter rape 3,800. There are 10-12 seeds per capsule (Salisbury, 1962). The 1,000 seed weight is given as 0.096 g. Seed size varies considerably on plants both within and between populations (Hurka & Benneweg, 1979). Part of this is due to genotype and part due to the environment. Plants growing in adverse conditions produce fewer but significantly larger seeds. In pot studies, shepherd's purse grown at a high density produced 210 seeds per plant and at a low density produced 23,000 seeds per plant (Palmblad, 1968). Flower spikes cut prematurely produce viable seeds from large unripe seed capsules but not from small immature fruits. Seeds from both dead-ripe and green capsules required a period of after-ripening before they would germinate (Gill, 1938). Three generations can occur each year (Salisbury, 1962). Some plants produce seed within 6 weeks of emerging. Seeds sown in May emerged in just 7 days. Seed rain from plants that emerged following cultivation in April extended from July to August (Leguizamón & Roberts, 1982). Seed numbers in soil increased from an initial 80 to a final 2,630 seeds per m^2 to 10 cm depth.

Freshly harvested seed is dormant and requires a period of stratification followed by exposure to light in order to germinate (Popay & Roberts, 1970a). The presence of nitrate can to some extent overcome the need for stratification. Burial of seeds in soil under natural conditions allows after-ripening to take place. Once a sufficient period has elapsed, seeds germinate readily on exposure to light. A period of 12-24 months burial may be required to remove dormancy in the majority of the seeds. Seed from plants that emerge later in the year will not germinate in that first autumn but may do so in the following spring or in some subsequent spring or autumn (Baskin *et al.*, 2004). Low winter temperatures maintain seed dormancy but mild spells in the autumn or spring cause some dormancy loss in a proportion of the seeds. The level of seed germination increased from 1 to 66% following a 10-month period of moist storage at 5°C (Grime *et al.*, 1981).

Dry-stored seed was buried outside in pots and exhumed at monthly intervals for germination testing (Milberg & Andersson, 1997; Andersson & Milberg, 1996). Seed germination occurred from July in year 1 and continued into the spring of year 2 with peaks in August-September and in February. There was little germination in the absence of light but a flash of light was more stimulating than a long period of illumination. Unchilled seed was not stimulated to germinate by light but after 2 weeks stratification at 4°C there was up to 40% germination in the light (Popay & Roberts, 1970b). Germination in darkness was much less. Stratification and light is needed for the germination of most seeds. Five days or less at 4°C is all that is needed. Fluctuations in temperature with an amplitude of 15°C or over increase the level of germination but the lower temperature needs to be 15°C or under. Nitrates increase germination rates under alternating temperatures. Increased levels of carbon dioxide inhibit seed germination (Karssen, 1980/81). Shallow burial inhibits germination possibly due to increased carbon dioxide and decreased oxygen levels, lower temperatures and a lack of light. Chilling in the light was more effective than chilling in the dark for relieving seed dormancy (Roberts & Benjamin, 1979). The maximum effect was achieved after 7 days and improved the ability of seeds to germinate under all conditions. Continuation of chilling beyond this period resulted in a re-induction of dormancy. Seeds naturally-occurring in field soil and concentrated down by washing/sieving and put into dishes, germinated only in the light and when temperature fluctuations were high (Warington, 1936).

In Kentucky, USA, seeds after-ripen in summer, are non-dormant in autumn-winter and become conditionally dormant as temperatures increase in early spring (Baskin & Baskin, 1989). Seeds will still germinate at temperatures that are normal for March-April but the increasing temperatures in spring induce non-dormant seed into dormancy and seeds lose the ability to germinate at higher temperatures. Seeds that after-ripen at 5°C will not then germinate at higher temperatures (Baskin & Baskin, 1986). Seeds that after-ripen at higher temperatures will germinate at a wide range of temperatures. It is thus a facultative winter annual germinating in both autumn and spring if seeds receive light. Some seeds retain the ability to germinate throughout the growing season. Most studies in the UK show that seed germinates throughout the year if soil is disturbed. The time from germination to fruiting is given as 100 days (Guyot *et al.*, 1962).

Seed sown in pans of field soil emerged mainly in spring but some seedlings emerged throughout the year (Brenchley & Warington, 1930). Seed was still emerging in year 3 of the experiment. Seed sown in a 75 mm layer of soil in cylinders sunk in the field and stirred periodically, emerged from February to November with peaks in May and September (Roberts, 1964). In mild periods seedling emergence may continue in December and January too. Rainfall influences the timing of seedling emergence. Seedling emergence in Scotland recorded in field plots dug at monthly intervals began in April and continued through until September/October with peaks in June and

August (Lawson *et al.*, 1974). Seed sown in early July emerged in the month after sowing (Salisbury, 1962). Few other seedlings appeared until a second flush emerged in January-February of the following year.

In Sweden shepherd's purse is considered a winter annual (Håkansson, 1979). Seeds mixed with soil in the autumn, put in frames in the field, exhumed at intervals and put to germinate at alternating temperatures showed the seeds to have the lowest dormancy and greatest tendency to germinate from April to November. Very few seedlings emerged in the autumn after sowing.

When seed was sown in boxes and pots outside in the field at different depths, cultivated or not, surface sown seed germinated in spring, summer or autumn but never in large numbers (Froud-Williams *et al.*, 1984). Seed buried at 50 mm produced similar results in year 1 but gave higher seedling numbers in year 2 whether cultivated or not. The optimum depth of emergence was 5-10 mm and the maximum 20 mm. In a sandy loam soil, field seedlings emerged from the upper 20 mm of soil with around 89% from the top 10 mm (Unpublished information).

Persistence and spread

Thompson *et al.* (1993) suggest that based on seed characters, shepherd's purse seed should persist for longer than 5 years in soil. Chepil (1946) found seed exhibited a period of dormancy of 3-5 years. Porter (1944) gives the longevity of seeds in soil as 35 years. However, Guyot *et al.* (1962) give the longevity in soil as just 2-3 years. Seeds mixed with soil and left undisturbed had declined by 77% after 6 years but in cultivated soil the decline was 96% (Roberts & Feast, 1973b). In Duvel's burial experiment, seed buried at 8, 22 and 42 inches gave poor germination initially but later gave 47% germination after 16 years burial at 42 inches (Toole, 1946; Goss, 1924). There was no germination after 21 years. In Beal's burial experiment, seed was still germinating after 35 years (Crocker, 1938). Seed buried in soil in subarctic conditions had 46, 18 and 2% viability after 2.7, 6.7 and 9.7 years respectively (Conn & Deck, 1995).

Seedbank decline was 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). The mean decline per year was 55% and the time to 99% decline was calculated to be 6.5 years. In naturally-occurring populations of shepherd's purse seeds in undisturbed soil, the annual loss was 27% (Roberts & Feast, 1973a). Shepherd's purse seed sown in the field and followed over a 5 year period in winter wheat or spring barley showed an annual decline of around 40% (Barralis *et al.*, 1988). Emerged seedlings represented 8% of the seedbank.

Seeds are passively dispersed around the parent plant as the fruits split open Hurka & Haase, 1982). Seed is small enough to be dispersed by the wind (Grime *et al.*, 1988). Seed transport over longer distances is facilitated by the mucilaginous seed coat. A thin layer of sticky mucilage forms when the seeds are moistened (Young & Evans, 1973). Seeds may adhere to bird's feet and be dispersed externally as well as internally. Seed has been found in sparrow droppings (Salisbury, 1961). Passage through a bird's digestive system may improve germination. The seeds are also dispersed in mud on tools, boots and tyres. Seeds in and on the soil are moved around by earthworms. Seeds are ingested by the worms and excreted in wormcasts (McRill, 1974). Undigested seeds excreted by the worms germinate but at a lower rate than the original seed. Earthworms are important in the dynamics of shepherd's purse seedbanks. Apparently-viable seeds have been found in samples of cow manure (Pleasant & Schlather, 1994). Seed was also found in cattle and goat droppings (Salisbury, 1961). Seed that had passed through a cow gave 24% germination (Horne, 1953). Seeds did not germinate after ensilage for 2 weeks (Zimdahl, 1993). Seed has been recovered from irrigation water in the USA (Kelley & Bruns, 1975). Seed submerged in water gave 50% germination after 9 months, 2% after 4 years and zero after 5 years (Comes *et al.*, 1978).

In a survey of grass seed contamination in 1960-61, shepherd's purse seed was found in 3.4% of Timothy, 2.0% of meadow fescue samples of English origin and in 2.2 and 1.4% of samples of Italian ryegrass of English and Irish origin respectively (Gooch, 1963). In clover and grass seed samples tested in Denmark for the period 1966-69, 1955-57, 1939 and 1927-28, shepherd's purse seed was a contaminant in 4.1, 3.4, 3.3 and 1.8% of samples respectively (Olesen & Jensen, 1969). In Timothy seed there was an average of 21 and a maximum of 400 shepherd's purse seeds per kg of clover seed.

Management

Control is by repeated surface cultivations, and by the tillage normally associated with root crops to deal with tap rooted weeds (Long, 1938). Prevention of seeding is important (Morse & Palmer, 1925). If necessary, bare fallowing and smother crops may be resorted to. While stubble cleaning may not be appropriate for dealing with the shed seeds of some weed species it can be an effective way of controlling some important weeds including shepherd's purse. The surface soil should be cultivated to a depth of not more than 5 cm and this operation is then repeated at 14-day intervals. Seedling numbers increase with increasing frequency of tillage (Pollard & Cussans, 1981). Studies with soil clods of different sizes and hardness showed that seed germination was less and fewer seedlings emerged from larger clods whether they were hard or soft (Terpstra, 1986). Both a lack of light and the depth of incorporation in the clods were factors in limiting germination and successful emergence.

In the USA, reduced tillage over a 2 year period in vegetable cropping on raised beds increased the density of shepherd's purse seeds in the 0-15 cm soil layer compared with conventional tillage (Fennimore & Jackson, 2003). The minimum tillage involved a single pass with an implement using disc blades and shovels to incorporate crop residues and till the raised beds while leaving them intact. The maximum tillage depth was 20 cm. Conventional tillage included sub-soiling, disking, bed formation and shaping and cultivation with a rolling cultivator. The maximum tillage depth was 50 cm. There was a suggestion that organic amendments including a rye cover crop and municipal compost reduced seed numbers in soil perhaps due to increased microbial activity. In a market garden rotation, shepherd's purse numbers doubled following the addition of organic manures to the soil whether these were based on farmyard manure or sewage sludge (Mann, 1957). There was no further rise in numbers by increasing the rate of manure from 15 to 30 tons per acre.

In a 2-year set-aside in Scotland, shepherd's purse seed numbers in the seedbank declined despite some seed setting in year 1 (Lawson *et al.*, 1992). The lack of seed set in year 2 was probably due to competition from taller vegetation. Shepherd's purse survives trampling, grazing and mowing due to the semi-rosette growth habit (Grime *et al.*, 1988).

In conventional horticultural systems, the frequency of shepherd's purse increases following winter brassica crops (Atkins & Burn, 1991). Over an 11-year period in an arable field cropped conventionally, shepherd's purse increased by flowering and setting seed after crop harvest in autumn (Chancellor, 1976).

Fallowing for 1 or 2 years had little effect on seed numbers in soil possibly due to seed return by small overwintering plants (Brenchley & Warington, 1933; 1936). The land was ploughed, disked and harrowed during fallowing. Cropping with winter wheat for the same period had a variable effect on seed numbers in different years. Fallowing at 5 year intervals over a 15 year period did not reduce seed numbers overall (Brenchley & Warington, 1945). Seed shedding presumably occurred at times during the intervening crop years.

Seedlings with 2-6 leaves are tolerant of flame weeding (Ascard, 1998). In studies to assess the use of ultraviolet-B radiation for selective weed control, shepherd's purse was relatively sensitive at both the 2-leaf and 12-leaf stage (Andreasen *et al.*, 1999; Furness & Upadhyaya, 2002). Leaf area and biomass declined and root biomass was also affected by treatment.

Laboratory studies with a limited volume of soil to simulate band steaming in the field investigated the effect of different temperatures following steaming for 60 or 90 seconds (Melander & Jørgensen, 2005; Melander *et al.*, 2002). The dose response curve constructed from the results was sigmoid with an abrupt change from no effect to over 90% control of seedling emergence at around 60^{o}C. Shepherd's purse seed is also susceptible to soil solarization.

Wheat gluten meal (WGM) at 1 or 3 g.dm^{-2} dusted over seeds put to germinate on moist paper reduced germination by 52 and 100% respectively (Gough & Carlstrom, 1999).

Geese will eat shepherd's purse and may be selective in certain crops (Quarles, 1999). The seed leaves are susceptible to attack by the flea beetle. The plants often suffer fungal attack (Salisbury, 1962).

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