

## The biology and non-chemical control of Field Penny-cress (*Thlaspi arvense* L.)

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### Field penny-cress

(Boor's mustard, bowyer's mustard, churl's mustard, dish mustard, mithridate mustard, stinkweed, treaclewort)

*Thlaspi arvense* L.

### Occurrence

An annual or overwintering plant, doubtfully native, sometimes plentiful on arable land. It is also frequent on disturbed and waste ground, and on roadsides (Clapham et al, 1987). Field penny-cress is scattered over most of the UK but commoner in England (Stace, 1997). It is frequent in southern and eastern England and scarcer in the west and north (Rich, 1991). It is not recorded above 1,000 ft in the UK (Salisbury, 1961). It is able to adapt to a range of environmental conditions and succeeds in both dry and wet habitats. Field penny-cress thrives in a nutrient rich, humus-containing or sandy-loam soil (Hanf, 1970). It is considered an indicator of such soils.

There is evidence that field penny-cress was a weed of crops in the Bronze Age (Greig, 1988). In a preliminary survey of arable weeds in the 1970's it was absent or rare in most of the areas studied but was common to frequent in 11% of them (Chancellor, 1977). Field penny-cress is a frequent bird seed alien (Hanson & Mason, 1985).

Genetically distinct early and late flowering forms have been reported in Canada (Best & McIntyre, 1975a; McIntyre & Best, 1975). During the summer, the two forms are distinguishable by leaf shape (Mitich, 1996). The leaves of late-flowering plants have longer petioles and deeper serrations or lobes than the early-flowering strain.

The seeds contain a glucoside that breaks down to form a mustard oil that can cause poisoning in stock (Best & McIntyre, 1975a). The plant smells strongly when crushed and taints the milk of cows that eat it (Frankton & Mulligan, 1970). The meat from animals that have eaten the weed is also tainted (Morse & Palmer, 1925). Nevertheless, field penny-cress is cultivated as a food plant in some countries. Oil can be extracted from the seeds but the composition is variable (Warwick *et al.*, 2002). The seeds act as a diuretic and were also taken to relieve rheumatism (Barker, 2001). An extract of pulverised penny-cress seeds inhibited the germination of lettuce and cress seed (Wagenvoort & Van Opstal, 1979).

### Biology

Field penny-cress flowers from (March) May to October and is generally self-pollinated. Out-crossing rates have been estimated at 10-20% (Warwick *et al.*, 2002). Flowering is hastened by increasing temperatures. In Canada, differences in flowering behaviour seem to be attributed to temperature effects. The flowering of early flowering forms is accelerated at higher temperatures but that of late flowering forms is delayed (McIntyre & Best, 1975). In controlled conditions at 16 hours

daylength and a constant 15°C, the early forms flowered after 30-50 days and the late forms flowered after 130-150 days. In the field, however, plants flowering in the field are a mixture of early and late flowering forms (Best & McIntyre, 1975b). Vernalisation by low temperatures appears to override the late flowering response but the stage of the seedlings and the duration of the low temperatures significantly affected flower development. The synchronised flowering of the early and late flowering strains permits some cross-pollination between the two forms. Although flowering is mainly autogamous, insects visit the flowers and some crossing is likely to occur.

Seedlings that emerge in the autumn overwinter as a rosette and flower early in the growing season. Stem elongation occurs with the onset of flowering (Best & McIntyre, 1975b). The earliest emerging seedlings produce the most seeds and those with the highest 1,000 seed weights. Plant size and branching habit is enhanced and flowering delayed by increasing nitrogen levels, seed production per plant is likely to be greater (Best & McIntyre, 1975a). Spring seedlings may flower within 30-50 days of emergence and produce seeds by early July. In cereal crops, field penny-cress seeds mature and shed before grain harvest.

The fruit is compressed and broadly winged. There are 3-8 seeds in each of the 2 locules (Rich, 1991). Field penny-cress has approximately 12 seeds per fruit and 20,000 seeds per plant according to Long (1938). The average seed number per plant is 1,023 (Pawlowski *et al.*, 1970). Salisbury (1961) gives the average seeds per fruit as 16 and the average seeds per plant as 2,000. Stevens (1932) gives the average seeds per plant as 7,040, Stevens (1957) quotes 900 to 2,000 seeds per plant while Best & McIntyre (1975a) suggest a single plant will produce 1,600 to 15,000 seeds. Guyot *et al.* (1962) give the seed number per plant as 800 to 1,000. The range of 1,000 seed weights given by different authors varied from 0.785 to 1.750 g (Stevens, 1932). Pekrun & Claupein (2006) give the 1,000 seed weight as 0.9 g.

Seed is generally mature 16 days after flowering but seeds can become viable after just 6 days (Baskin & Baskin, 1989). Seed is shed over several weeks (Best & McIntyre, 1975a). It is said that fresh seed will germinate in the light with adequate moisture and alternating temperatures. In laboratory tests, there was good germination at alternating temperatures of 10-25°C in the light. Scarification of the seed coat promotes germination. In Petri-dish tests, seed in the light germinated up to 39% at a constant 18-20°C and up to 94% at alternating temperatures of 20 to 30°C (Cross, 1930-33). Dry-stored seed did not germinate under constant temperature with or without light (Wagenvoort & Van Opstal, 1979). Even with alternating temperatures there was less than 10% germination. Germination reached 50% when the seeds were treated with fertilizer solution and alternating temperatures and, following stratification for 2 days at 5°C, the level of germination increased further. Nitrate did not stimulate germination in the dark at constant or alternating temperatures (Saini *et al.*, 1987). A combination of nitrate, light and a shift in temperature from 12 to 22°C after 4 days induced 100% germination. Seed stratified outdoors in soil overwinter was exhumed and tested for germination in the light, in the dark and in the dark with a 5 second flash of light (Andersson *et al.*, 1997). Seed gave more than 80% germination in the light and in the dark with a short flash of light but only 1% germination in complete darkness. Seed dormancy was overcome by chilling at between 5 and 15°C but light was still needed for germination (Hartmann *et*

*al.*, 1996). Without light, seeds gradually returned to a dormant state. The addition of nitrate broke the dormancy of field pennycress seeds where there had been negligible germination previously (Milberg, 1997). The presence of nitrate was also important in making light stimulation more effective.

In controlled environment studies, freshly shed seed from an inbred line with a cold requirement for flowering exhibited primary dormancy that was lost following 1 month of after-ripening in a dry state at 6 or 23°C (Hazebroek & Metzger, 1990). Germination was promoted by red light and inhibited by far red light. Germination and emergence of field penny-cress seed was also inhibited when light was filtered through a canopy of leaves. Maintaining imbibed non-dormant seeds at 6°C for 2 weeks induced secondary dormancy unless seeds had been held at 21°C for 48 hours previously. Germination was comparatively sensitive to dry conditions, water potentials of -10 bar or lower prevented germination. Wheat and wild oat (*Avena fatua*) were able to germinate at much lower values. Fresh seed of early and late flowering forms incubated at alternating temperatures of 10/25°C germinated to 95% in the light (McIntyre & Best, 1975). At a constant 25°C seed of the early flowering form gave 45% germination but none of the late flowering seed germinated.

Seeds washed out from the soil seedbank gave 100% germination in diffuse light at temperatures ranging from 20-26°C whatever time of year they were recovered and tested (Bibbey, 1948). Freshly shed seed required a period of after-ripening over the autumn/winter period, but the length of time needed depended on the depth of burial and the soil type. Reduced oxygen levels inhibited seed germination. In greenhouse studies there was optimal emergence when seeds were at or near the soil surface but moisture was important (Boyd & Van Acker, 2003).

In Sweden field pennycress 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. Many seedlings emerged in the autumn after sowing.

In the USA, field penny-cress may behave as either a summer or winter annual (Baskin & Baskin, 1989). Freshly matured seeds in April-May are dormant until after-ripening has occurred in summer. Plants from seeds that germinate in autumn overwinter as rosettes and flower in spring. Seeds produced in autumn after-ripen over the winter and germinate in early spring. Plants from seeds that germinate in spring, flower and set seed later the same year. Soil disturbance increases the level of germination because of light stimulation. Seeds that are non-dormant in autumn but are unable to germinate at that time become conditionally dormant or dormant at low winter temperatures.

Seed sown in a 75 mm layer of soil in cylinders sunk in the field and stirred periodically, emerged from February to October with the main flush from February to June (Roberts, 1964). Substantial numbers of seeds germinated in the first 4 years from seed sown in trays of soil in the field but most emerged in year 1 (Chepil, 1946a). When seeds in trays of soil in the field were given different cultural treatments the highest percentage of germination was from seeds left on the soil surface (Chepil, 1946b). The deeper that seeds were buried, the lower the number of

emerged seedlings and the greater the number of seeds that survived to the end of the experiment. Periodic cultivations increased seedling emergence. In a sandy loam soil, field seedlings emerged from the top 50 mm of soil with most coming from the upper 30 mm (Unpublished information).

### **Persistence and Spread**

Thompson *et al.* (1993) suggest that based on seed characters, field penny-cress seed should persist for longer than 5 years in soil. Seed exhibits a dormancy period in excess of 3 years (Chepil, 1946a). Seeds remain viable in soil for at least 8 years (Salisbury, 1961). Seeds have survived up to 10 years in soil and still given 87% germination. Guyot *et al.* (1962) also give the longevity of seeds in soil as 8-10 years. Porter (1944), however, records the longevity of seeds in soil as 20 or more years. In Duvel's burial experiment, seed buried at 8, 22 and 42 inches gave 11, 8 and 12% germination respectively after 1 year, 34, 52 and 8% after 6 years, 0, 11 and 1% after 30 years and none after 39 years (Toole, 1946; Goss, 1924). But in cultivated soil few seeds survived longer than 6 years (Best & McIntyre, 1975a). Seeds mixed with soil and left undisturbed had declined by 52% after 6 years but in cultivated soil the decline was 92% (Roberts & Feast, 1973). Dry-stored seed gave 80% germination after 1 year but nil after 2-5 years (Kjaer, 1940).

Seeds will float in water for 24 hours (Best & McIntyre, 1975a). Seed is also said to be dispersed by the wind. Viable seeds have been found in pigeon droppings and seedlings have been raised from the excreta of various birds (Salisbury, 1961). Apparently-viable seeds were found in samples of cow manure (Pleasant & Schlather, 1994). Ensilage for 8 weeks, rumen digestion in cattle for 24 hrs or a combination of both seemed to kill field penny-cress seed but some still appeared viable (Blackshaw & Rode, 1991). With rumen digestion, there was a gradual loss of viability to 30% after 24 hrs in one test but in another 98% of seeds were still able to germinate following rumen digestion. After 2 weeks of windrow composting at temperatures of 50-65°C, field penny-cress seeds were all killed (Tompkins *et al.*, 1998). Seeds were also killed when heated at 85°C for 15 minutes using dry heat (Hopkins, 1936).

### **Management**

Laying land down to a ley for 3-4 years will choke out the weed. Field penny-cress showed no consistent response to conventional, minimum and zero tillage regimes at a range of sites (Warwick *et al.*, 2002). Germination should be encouraged by surface cultivation. Seed bearing plants should not be ploughed-in. It is important to prevent seeding by destroying plants when young with the harrow, cultivator or hoe (Morse & Palmer, 1925). Field penny-cress seedlings can be hoed off readily in root crops (Long, 1938). In mechanical weed control studies, field penny-cress was uprooted with less force than carrots at the same development stage.

In conventional horticultural systems, the frequency of field penny-cress increases following summer brassica crops (Atkins & Burn, 1991).

The weed was found to increase markedly following a series of spring cereals (Rademacher *et al.*, 1970). A preliminary study in Sweden demonstrated that the number of weed seeds left on the ground after harvesting oats by combine was much higher than when the crop was harvested with a binder, dried in shocks and then

threshed elsewhere (Åberg, 1956). There were over 6 times more field penny-cress seeds recorded on the soil surface when the oats had been combine harvested.

The presence of nitrate is important for making light stimulation more effective (Milberg, 1997). On the basis of this, it has been suggested that spring cultivations should be made in unfertilised soil and that fertiliser application should be left until after crop and weed emergence.

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