The biology and non-chemical control of common couch
(*Elytrigia repens* (L.) Nevski)

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Common Couch
(couch, couchgrass, quackgrass, quicks, scutch, squitch, twitch, wickens, wicks)
Elytrigia repens **(L.) Nevski**
(*Agropyron repens* (L.) Beauv.; *Elymus repens* (L.) Gould; *Triticum repens* L.)

Occurrence
Common couch is a native perennial grass found throughout the British Isles on cultivated, waste and rough ground (Clapham *et al*., 1987; Stace, 1997). It is a common garden weed (Copson & Roberts, 1991). Common couch occurs on both heavy and light soils (Brenchley 1911; 1913), but is able to spread more readily on lighter land (Salisbury, 1962). It grows on most soil types except those with a low pH but prefers heavier soils. Common couch has a preference for fine, stone-free soils low in organic matter of pH 6.5 to 7.8 and with a high vegetation cover (Dale *et al.,* 1965).

The potential distribution of common couch has been mapped using botanical survey and soil survey data (Firbank *et al.,* 1998). The probable distribution was seen to be closely correlated with the distribution of arable land. Common couch is concentrated in the hedge bottoms and field margins (Marshall, 1985). It rapidly spreads out from the field margins into cultivated fields. In a survey of conventional cereal crops in central southern England in 1982 the most frequent grass weed was couch which was found in 42% of winter wheat, 14% of winter barley and 31% of spring barley fields (Chancellor & Froud-Williams, 1984). In the UK, common couch was considered to be more abundant in the 1990's than it had been in the 1960's (Marshall *et al.*, 2003). It remained widespread between 1978 and 1990 despite increased herbicide use (Firbank, 1999). In Finland too there was an increase in the frequency of common couch in conventional spring cereals in the period 1980 to 1990 (Hyvönen *et al.,* 2003). This may reflect a change in the rate or type of herbicides used. However, in Denmark, a comparison of weed surveys made in spring barley in 1970 and 1989 showed that there had been a dramatic decrease in common couch frequency due to the extensive herbicide use (Streibig *et al.,* 1993). In a survey of UK cereal field margins recorded as part of Countryside 2000, common couch was the third most frequent species recorded (Firbank *et al.,* 2002). In a 3-year set-aside, common couch frequency exhibited some decline with increasing distance from the field edge but distribution was patchy (Rew *et al.,* 1992). In a comparison of the ranking of arable weed species in unsprayed crop edges in the Netherlands in 1956 and in 1993, common couch remained in 6th place (Joenje & Kleijn, 1994). In a series of 4 national weed surveys made in Hungary between 1950 and 1997, common couch moved from 27th to 12th place in the rankings (Tóth *et al.,* 1999; 1997). In a survey to identify the main weed species causing problems in organic farming in the new EU member states and the acceding countries, common couch was the main problem grass weed identified (Glemnitz *et al.,* 2007).

In a study of seedbanks in some arable soils in the English midlands sampled in 1972-3, common couch was recorded in 50% of fields sampled in Oxfordshire and 6% in Warwickshire but never in large numbers (Roberts & Chancellor, 1986). Couch seed was found in less than 1% of arable soils in a seedbank survey in Scotland in 1972-1978 (Warwick, 1984). In a survey of seeds in pasture soils in the Netherlands in 1966, while common couch was frequent in the sward it was not represented in the soil seedbank (Van Altena & Minderhoud, 1972). In other studies comparing weed vegetation with the soil seedbank, common couch was also well represented in the vegetation but absent from the soil seedbank (Hill *et al.*, 1989).

Common couch can form dense stands that exclude other vegetation (Weber, 2003). However, it is not resistant to treading and does not persist on well-used paths that cross grassed areas (Bates, 1935). Couch growth is especially vigorous on fallow land and in the first years after tillage ceases (Werner & Rioux, 1977). It may make up to 90% of the biomass in an abandoned field for several years preventing colonization by dicotyledonous species. Couch is sensitive to shading, however, and when scrub take over the grass gradually dies out. In set-aside land in Scotland, perennial grasses in general and common couch in particular made up a significant proportion of the vegetation after the first 2 years (Fisher *et al.*, 1992). Old permanent pastures tend to have little couch present (Long, 1938). Nevertheless, Peel and Hopkins (1980) found that infestations were as common in swards over 20 years old as on recently sown swards. In a survey of 502 grassland farms couch was found to affect 1% of all fields but was more common in eastern England where 10% of fields were infested with it. It was recorded more often on dairy farms than beef farms.

Common couch thrives in cooler climates and is one of the most serious weeds in the Northern temperate zone but is absent from the tropics (Palmer & Sagar, 1963). As a C_3 plant, in terms of photosynthetic pathways, couch is not well adapted to hot dry climates (Håkansson, 2003). At higher temperatures biomass production is lowered and the allocation of photosynthates to the underground organs decreases. Rhizome production is reduced, limiting the plants invasiveness. In South America and other warm countries, it may grow in cooler mountain regions (Holm *et al.*, 1977). The aerial shoots do not appear to be harmed by freezing but a few days exposure to frost is said to kill rhizomes left on the soil surface (Håkansson, 2003). However, when the freezing resistance of overwintering rhizome buds of common couch was evaluated in the laboratory the temperature required to reduce survival by 50% was colder than –20°C. (Schimming & Messersmith, 1988).

Varietal names have been given to several recognised forms or clones (Palmer & Sagar, 1963).

Common couch like other grasses is an alternative hosts for the frit and gout flies (Morse & Palmer, 1925). It is a carrier of take-all disease of cereals, *Ophiobulus graminis*, the disease being present in the rhizome internodes (Hughes, 1966; Moore & Thurston, 1970). It can also be infected with several other fungal diseases that affect cereals including ergot (*Claviceps purpurea*), barley leaf blotch (*Rhynchosporium secalis*) and cereal wilt (C*ephalosporium gramineum*) (Thurston, 1970; Moore & Thurston, 1970). Common couch growing in barley may harbour a species of root lesion nematode (*Pratylenchus* spp.) that also attacks the crop (Franklin, 1970).

Reviews of common couch have been made previously by Palmer & Sagar (1963), Holm *et al*. (1977), Werner & Rioux (1977) and Boyall *et al*. (1981).

Biology
Aerial shoots may initiate flowers during April or early May that open in May, June or July. Couch requires a minimum temperature of 23°C for flowering. The flowering period extends from June to September (MAFF, 1974; Clapham *et al*., 1987). Couch is self-sterile and a large patch may consist of a single clone but as the flowers are wind pollinated, fertilisation is not necessarily a problem (Werner & Rioux, 1977). A high level of seed production has been recorded (Sagar, 1960).

The seed heads mature during August and September at around the time of cereal harvest. Many seeds are viable when green and immature (Williams, 1971). Around 20% of the total number of viable seeds was viable 10-18 days after flowering depending on prevailing conditions. Viable seeds were found in around 95% of flower spikes of couch collected shortly before harvest from a range of crops, predominantly cereals (Williams & Attwood, 1971). Plants may produce up to 400 seeds per flower stem but 25-40 is more usual of which on average 13 are viable. Seed samples collected within 3 weeks of the assumed flowering date showed much less germination than those collected later. The percentage germination increased the later the date of sampling. There was a 1% increase for each additional day after 15th July.

Common couch seed does not require an after-ripening period and can germinate anytime after shedding if conditions are right. Laboratory studies suggest that diurnal fluctuations in temperature with an amplitude of 4°C promote germination in the light (Thompson *et al.,* 1977). Light is of little importance, but fresh seed requires the temperature to alternate between 15 and 25°C for germination to occur. Seed will not germinate under constant temperatures (Palmer & Sagar, 1963). Seeds appear indifferent to light, however, when seeds were put to germinate under a leaf canopy or in diffuse white light there was just 4% germination under the canopy and 90% in the light (Górski *et al.,* 1977). The seeds germinate mainly during autumn in the UK but germination may be delayed by cold temperatures, inadequate moisture or deep burial (Williams, 1971). Seed buried at 5 cm deep all germinated and emerged but only 4% of seed buried at 10 cm deep emerged and none at 12.5 or 15 cm. In greenhouse studies emergence from seeds on the soil surface was significantly less than from 1-2 cm deep (Boyd & Van Acker, 2003).

In Sweden, common couch 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 May (Håkansson, 1979). The seeds exhibited little dormancy under any conditions. Many seedlings emerged in the autumn after sowing, and most of the remaining seeds germinated in the following spring.

According to Werner & Rioux (1977), germination normally occurs in early spring which is true in many countries including Sweden and Russia. The seedlings begin to tiller at the 4-6 leaf stage and produce rhizomes at the 6-8 leaf stage. Håkansson (1970a), however, found that seedlings began to develop rhizomes at the 4-5 leaf

stage in mid- to late-June. Subsequent development of plants from seed was similar to that of plants growing from rhizome pieces (Håkansson, 1967). The young seedlings are unable to regenerate vegetatively until rhizomes several centimetres long have developed. Large variations occur in the growth and morphology of seedlings from seeds collected in different areas even when grown under relatively uniform conditions (Williams, 1973a). Variation between seedlings and clones in the number of shoots per plant was very great. It was noted that plants with the least shoot weight had the most rhizomes.

Vegetative reproduction in common couch is far more important than from seed but like the seeds, rhizome pieces from different clones demonstrate differences in growth physiology under similar conditions (Pooswang *et al.,* 1972). The depth at which the majority of rhizome buds develop in the soil can also differ between clones (Mortimer & McMahon, 1982). In some, the majority of buds occur in the top 10 cm of the soil profile while in others most buds are in the 10 to 20 cm layer. Some buds are found below 20 cm deep but not below 40 cm.   In compacted soil, the rhizomes grow more or less horizontally. The rhizomes are very shallow where infested land has been down to grass for many years (Frankton & Mulligan, 1970). In undisturbed arable land a mat of young rhizomes is found in the top 10 cm of soil at the end of the growing season. In uncultivated land with a layer of deep litter the rhizomes may grow above the soil surface under the litter. In pasture, couch has short rhizomes and apical dominance maintains buds in a dormant state. In loose soils the rhizomes grow down at an angle of 5-10° to the horizontal and may reach depths of 40 cm (Palmer & Sagar, 1963).

Rhizome growth is renewed annually from axillary buds that develop in the crown tissue at the base of the aerial shoots, and in the transition zone between shoot and rhizome (Håkansson, 1982). Rhizomes grow horizontally beneath the soil in late spring and summer before turning erect in autumn ready to form a primary aerial shoots that survive the winter. At this time, the aerial shoots of the parent plant die. The new shoots develop tillers and rhizomes in spring (Sagar, 1960). The same transformation occurs anytime that the parent plant or rhizome is disturbed by cultivation (Palmer & Sagar, 1963). Aerial shoots that develop in spring die in autumn or early winter (Werner & Rioux, 1977). Shoots that develop later in the season may survive the winter to a greater or lesser extent (Håkansson, 1982).

At first the rudimentary aerial shoot has only a few transitional leaves and one small shoot leaf (Palmer, 1958). The primary shoot emerges during the autumn, grows slowly over-winter and by spring has 2-3 mature aerial leaves. Once the soil temperature consistently exceeds 0°C new roots and primary aerial shoots begin to grow (Håkansson, 1982). In late March or early April active growth begins, new leaves are produced in rapid succession and the stem quickly elongates. The dormant buds at the base of each shoot grow out to form either upright tillers that resemble the aerial shoot or horizontal rhizomes. In a closed community each primary shoot typically produces three tillers and 3-4 rhizomes. In an open or disturbed community the primary shoots produce a tuft of tillers and develop abundant rhizomes.   The rhizomes themselves form numerous lateral rhizomes in July. A plant may produce 150 rhizomes in the first growing season. The rhizomes generally reach lengths of 50 cm before the tips turn erect. In one growing season a rhizome may attain a length of 2 m but in a closed community maximums of 5-15 cm are more common (Palmer,

1958). Most shoots emerge from the apices of secondary rhizomes (Mortimer & McMahon, 1982). Infestations of common couch show a regular spatial arrangement of shoots.

At high soil nitrogen levels tiller production increased leading to an increase in the development of secondary rhizomes (McIntyre, 1965). An increase in the nitrogen supply also reduces apical dominance in the rhizomes leading to the development of more lateral buds. The loss of apical dominance probably results from a reduction in the competition for nutrients within the rhizome. In rhizomes that were detached from the parent plant, even at high nitrogen levels, apical dominance was restored as the competition for the more limited supply of nutrients increased (McIntyre, 1969).

Common couch plants growing alone on recently disturbed soil produce considerably greater rhizome growth than those growing in established patches (Sagar, 1960). In undisturbed soil, where no fragmentation occurs, the majority of buds remain inactive due to apical dominance from the actively growing shoots. The parent rhizome may survive for two or more seasons depending on soil conditions and the frequency of cultivations. In well-established stands the soil beneath the surface may become crowded with a mat of rhizomes of mixed ages. Rhizomes normally die in the 3rd year after production. Only the most recently formed rhizomes are growing actively but all the living rhizomes are capable of regenerating if disturbed or fragmented. The old parent shoots die back in autumn, occasionally buds grow out from the old stock and produce rhizomes and tillers.

Temperature and light levels can affect couch development, all buds have the potential to develop either as shoots or rhizomes and environmental conditions can influence the result. Low constant temperatures favour the growth of underground organs in the winter (Palmer & Sagar, 1963; McIntyre, 1967). Higher temperatures encourage top growth at the expense of the rhizomes. Temperatures above 35°C depress all growth. Bud development at the base of new shoots is dependant on light intensity. At lower light levels, more buds develop into shoots and rhizome production is inhibited. In longer photoperiods and higher light levels rhizomes are thicker and more numerous (Werner & Rioux, 1977). The strongest couch growth is achieved at low temperatures in long photoperiods. At high temperatures and short photoperiods growth is depressed. In the USA, Majek et al. (1984) found that the rhizome tips curved upwards when grown at 32 or 10°C or given less than 10 hours light. Shading reduces plant growth, rhizome development being more affected than top growth (Håkansson, 1969b; Williams, 1970a; Skuterud, 1984). Plant height is increased at a light intensity of 50 or 25% of full daylight but shoot number is reduced. Shading later in the season, when the production of new rhizomes takes place, reduces rhizome production more than early shading. Rhizome growth is not affected by flower formation but growth ceases during mid-August to mid-October when the aerial shoots become senescent or growing conditions become unfavourable (Palmer & Sagar, 1963). The effect of nitrogen levels on bud development varied with the axillary position of the bud (McIntyre, 1967). At high nitrogen levels the bud in the axil of leaf one develops into tillers, at low nitrogen levels the buds form rhizomes.

Couch rhizomes exhibit the minimum regenerative capacity after deep burial in May (Håkansson, 2003). Low bud activity in spring is thought to be due to low food

reserves causing low regenerative capacity (Leakey *et al.*, 1977a). Rhizome buds decrease in activity from mid-April to June and then increase again from July onwards. New rhizomes develop below ground in the greatest numbers during July-August. Tillers and new rhizomes start to develop when the dry matter in the underground organs has exceeded a minimum level after the decrease due to early root and shoot development. This generally occurs when primary shoots have 3-4 visible leaves. Subsequent undisturbed growth allows a gradual dry matter increase that proceeds until autumn.

When a rhizome is separated from the parent plant, the axillary buds develop into aerial shoots that grow vertically upward (Palmer & Sagar, 1963). Cultivation may therefore displace the seasonal growing cycle. Renewed tillering and rhizome production will follow soil disturbance at any time except mid-winter. The stem bases of the aerial shoots also possess a regenerative capacity and can develop into new plants after fragmentation (Håkansson, 1969a). Shoots had a lower capacity for recovery from burial when they had 3-4 leaves than at any other stage (Håkansson, 1969c). Repeated burial at intervals of 1-4 weeks killed couch shoots when this began early in the year. Later in the year, shoots had a greater capacity for survival possibly due to the larger stem system. The shoots died but basal parts survived and new shoots developed from lower buds. Couch has a great capacity for regeneration after tillage even during the weakest stages of growth (Håkansson, 1995).

Shoots from single bud rhizome fragments begin to form new rhizomes at the 3 to 4-leaf stage. With single node fragments the greatest regenerative capacity was between November and April and the least was in June. The poor regeneration in June and July can be improved by applying nitrogen (Leakey *et al.*, 1977b). In rhizome fragments collected in May–July, and having late spring dormancy, the percentage of active buds increased with increasing potassium nitrate concentration. Chilling slightly increased active bud numbers. Shoot growth was generally greater from fragments of the current year's rhizome than the previous year's but chilling for 2 weeks at $-2^{o}C$ stimulated the growth of older rhizome pieces. Even under cool soil temperatures, cultivation and fragmentation will stimulate rhizome buds to sprout (Cussans, 1972a). Bud production on rhizome segments continues well into the winter (Lemieux *et al.*, 1993).

In the USA, rhizomes were sampled at intervals and the growth of single bud segments was assessed in the laboratory (Johnson & Buchholtz, 1962). Buds were fully active in late-March and early-April but decreased in activity from mid-April to early-June when the buds became dormant. The activity resumed in July and continued through the summer. This period of bud inactivity that occurs despite favourable growing conditions is referred to as late-spring dormancy. It differs from summer dormancy, which may occur in hot dry conditions.

It appears that at certain times of year but not always, the original node position of a rhizome fragment influences its regenerative capacity (Leakey *et al.*, 1977b). In rhizome pieces collected in autumn, regenerative capacity was greater in fragments from near the apices of the rhizomes and least from basal fragments. This may be related to differences in the nitrogen gradient found in spring and autumn. It suggests that unlike seed dormancy, rhizome dormancy may be related to nitrogen levels.

In experiments with rhizome pieces 4 to 32 cm long planted 0-30 cm deep in soil, most shoots emerged from rhizomes in the top 7.5 cm of soil, with a peak at 2.5 cm depth. The 32 cm fragments were able to emerge from up to 30 cm deep but most emergence was from 2.5-10 cm deep (Håkansson, 1968a). It was noted that death rates for planted rhizomes increased with depth and decreased with rhizome length except on the soil surface where conditions were not conducive to rhizome survival (Håkansson, 1969a). The optimum depth for survival was 5 to 10 cm. Regardless of planting depth, most new rhizomes that develop from buried fragments were found in the surface 10 cm of soil. The number of rhizome pieces that survived and sent out aerial shoots was much lower for 4-8 cm pieces than longer ones (Håkansson, 1968b). Greater survival of longer pieces is partly because of greater food reserves and partly because rotting from the ends kills shorter fragments quicker. Weak shoots developed from short rhizome pieces, the longer the rhizome segment the stronger the shoot (Vengris, 1962). In greenhouse tests, small rhizome fragments with one or two nodes buried in sandy loam soil at depths of 30, 60 or 90 cm produced shoots but only those from the 2-node fragments were able to emerge above ground and then only from 30 cm deep (Chancellor, 1966). The maximum shoot length on 2-node fragments was 53 cm. Shoots on the 1-node fragments grew to a maximum of 16 cm.

In a given area, more shoots are produced when cultivations cut rhizomes into smaller pieces but the shoots are less vigorous than those on longer fragments (Proctor, 1972). Rhizome mortality is also greater with smaller rhizome pieces. There is competition between the regenerating rhizomes and elongation of individual rhizomes is much greater when the couch population is low.

It is considered by many that common couch never develops a real innate dormancy and soil cultivation resulting in decapitation of the rhizome in any season when conditions are favourable causes immediate regrowth. The nearest bud to the apical end develops into a shoot, buds a little further from the apex produce rhizomes (McIntyre, 1970). The renewed growth follows a pattern of morphological and dry matter changes similar to that in spring. After extensive rhizome fragmentation at least one bud per fragment develops a new shoot except in winter when low temperatures retard growth. Leakey *et al.,* (1972a), however, have reported the occurrence of innate dormancy in 1-node rhizome fragments. This late spring dormancy, as it was termed, was greatest in June and July and lowest between October and May. There was little difference between young and old rhizomes. The dormancy is broken by nitrogen and it is suggested that nitrogen in the soil prevents dormancy occurring in the field.

Light inhibited bud growth in multi-node fragments incubated at 23°C but this could be reversed by transfer to darkness (Leakey *et al.,* 1978b). There was no inhibition if fragments were sprouted for 3 days in darkness before exposure to the light. In darkness, shoot growth occurred within 4 days but in the light it was delayed for at least 28 days or prevented completely. The position of the fragment on the intact rhizome may have an effect on this. In the dark, the percentage of active growth was at a maximum within 5-6 days and dominance by a single developing shoot was imposed within about 4 weeks. In the light, where activity was delayed but not prevented, the period of bud activity was extended and in some instances dominance did not develop. In the absence of dominance all the shoots grew. The spectral

quality of the light, especially wavelengths around 700 nm, appears to be important for the effect on dominance.

Where fragments have several buds some will remain dormant due to correlative dominance. However, it has been noted that buds are not completely inhibited for a 10-20 day period after fragmentation. Around 70-80% of buds on 7 and 15 node fragments were found to have made detectable growth in that period, only buds at the basal end of longer rhizome pieces remained dormant (Chancellor, 1968). On short fragments, all the buds made significant amounts of growth until the leading bud re-imposed dominance. The longer these shoots develop before growth ceases, the more vulnerable they become to subsequent cultivations. If the lead shoot dies for any reason, the inhibited shoots recommence growth to replace it. When 7 node rhizome fragments were incubated in the dark at 23°C, after an initial flood of activity, buds were inhibited in a highly ordered sequence leaving only 1 dominant bud growing (Leakey *et al.,* 1978a). At 13 to 23°C dominance was established in 30 days, at 3°C dominance took 170 days to fully establish, at 33°C only 6% had established dominance after 65 days. Applications of nitrate delayed the onset of dominance and increased shoot growth.

The angle that decapitated rhizomes are left at in the soil following cultivation can influence which of the new shoots that develop will exert dominance (Leakey *et al.*, 1972b). In rhizomes with the apical end pointing down the bud at the first node became dominant. In rhizomes with the apical end pointing up or horizontal, it was the bud at the second node that exerted dominance. The rate of bud growth and the time for dominance to develop were hastened at higher temperatures.

Growth is slowed under dry conditions (Cussans, 1972a). However, pieces of couch rhizome have demonstrated considerable resistance to drought (Håkansson, 1970b). Couch appears able to tolerate drought because plant metabolism falls under dry conditions. In this state, the rhizomes are much less susceptible to desiccation. Plant growth is restricted, preventing the depletion of food reserves and limiting the success of control by soil tillage.

In petri-dish tests, water extracts from plant residues of common couch inhibited the germination of lettuce and radish but had less effect on clover and wheat seed (Carley & Watson, 1968). The root and hypocotyl length of seedlings of all the test species except wheat was considerably reduced. In culture solutions, the growth of winter wheat roots was severely reduced by the roots of common couch (Sagar & Ferdinandez, 1976).

Persistence and spread
Common couch seeds are not innately dormant and most germinate during the first autumn (Williams, 1978). Seeds germinate most readily when shallowly incorporated in soil and persist longer when left on the soil surface. Seed may exhibit seed dormancy in excess of 3 years but seed sown in trays of soil in the field emerged mainly in the first year (Chepil, 1946). Few seedlings emerged in year 3. Seed can remain viable in undisturbed soil for more than 5 years (Salisbury, 1961). Only 7% of seed remained viable in soil for longer than 1 year (Chancellor, 1982). In Duvel's seed burial experiment 19% of seeds buried at 42 inches were remained viable after 4 years but only 1% at 22 and none at 8 inches deep (Toole & Browne, 1946; Goss,

1924). After 10 years, 2% of seeds were still viable at 42 inches deep but none at the shallower depths, and none remained alive at any depth after 16 years. Seed buried in soil in subarctic conditions had <1% viability after 2.7 years (Conn & Deck, 1995).

Common couch is usually introduced into new areas as seeds (McRostie *et al.,* 1932). Weed seed contamination of crop seed was a common source of couch infestations. In a survey of cereal seed drilled in 1970 on UK farms couch seed was found in 39% of samples from home saved seed and 5% of merchants seed samples (Tonkin & Phillipson, 1973). Sowing couch seed with the crop seed may not only contaminate clean land but may also introduce new clones to areas previously occupied by a single clone, thereby facilitating further seed production (Mackay, 1964). Combine harvesting a cereal with seed heads of common couch present will spread the seeds as efficiently as a seed drill (Sagar, 1960).

Common couch seed was found in 2-4% of cereal seed samples tested by the Official Seed Testing Station in 1960/61, an increase since 1951/52 (Gooch, 1963). In purity tests made on wheat, barley and oat seeds between 1961 and 1968 common couch seed was found around 3% of samples from 1961-67 but in 1967/8 the frequency in all the cereals had increased to over 5% (Tonkin, 1968a). In most seasons common couch was the most frequent injurious weed in samples of wheat, oats and rye (Tonkin, 1968b). In the period 1978-1981, common couch seed was found in 10-25% of wheat and 11-19% of barley seed samples tested (Tonkin, 1982). At the Official Seed Testing Station for Scotland the incidence of common couch and other weed seeds in certified and pre-certified barley seed 1996/97 showed that seed of couch was present in 31.5% of pre-certified samples and 6.3% of certified samples (Don, 1997). While the incidence of most weed seeds in certified barley seed samples has decreased, there was a regular increase in couch seed from its occurrence in 0.76% of 1986/7 samples, to 3.58% in 1991/2 to 6.26% in 1996/7. A similar increase was reported in certified oat and wheat seed samples. The results are thought to be due to an increase in couch infestations following its introduction in contaminated cereal seed!

In seed samples tested by the Official Seed Testing Station in 1960-61, common couch seeds were found in up to 13.8% of perennial ryegrass seed samples of UK origin and in up to 7.5% of samples of other grass seeds (Gooch, 1963). Up to 63.7% of grass seeds of Scandinavian origin were found to contain couch seed. The seed was not an important contaminant in clover, forage, root and vegetable seed samples tested at this time. In clover and grass seed samples tested in Denmark for the period 1927/8, 1939, 1955/57 and1966/1969, common couch was a frequent contaminant being found in 4.2, 9.6, 18.6 and 26.4% of samples tested respectively (Olesen & Jensen, 1969). It was most frequent in seed of perennial ryegrass and red fescue.

Common couch seed retains viability after passage through the digestive systems of horses, cows and sheep but not pigs (Mitich, 1987). Apparently-viable seed has been found in samples of cow manure (Pleasant & Schlather, 1994). Seed has been recovered from irrigation water in the USA (Kelley & Bruns, 1975). Seed stored in freshwater for 27 months did not germinate (Zimdahl, 1993).

Field margins infested with common couch act as a source for repeated spread into arable fields. The rhizomes extend readily into cultivated soil. Once there, tillage

fragments the rhizomes and scatters the pieces further into the field. Seed may be a more important source of new infestation than is realised and common couch allowed to flower in the margins could set seed that would be readily dispersed within the field or beyond. A single node rhizome fragment has produced over 80 m of growth in a 12-month period (McRostie *et al.,* 1932). In a 3-year old grassland in the USA only 33% of the rhizome mat was viable (Johnson & Buchholtz, 1962). New rhizomes develop as older ones decay, keeping the proportion of viable rhizomes constant.

Management
Although vegetative propagation is considered to be the main source of spread it is important to ensure that new infestations are not introduced as seeds in contaminated grass or cereal seed (MAFF, 1949). Once couch is established repeated ploughing, grubbing and harrowing must be practiced to reduce it (Long, 1938). The land should be ploughed shallowly and as much weed as possible collected by grubbing and harrowing when the soil is dry. The weed should be burnt and the ashes spread on the land. Isolated patches may be forked out and burnt (Weber, 2003). Machinery has been developed with two banks of rigid soil-loosening tines fitted with 30 cm wide wing- or duck-foot shares that tear up the stubble ahead of a pto-driven horizontal rotating shaft fitted with long curved tines (Anon, 2005). These flick the rhizomes out onto the soil surface where they can be left to desiccate or can be collected up for burning (Van der Schans & Bleeker, 2006).

In western Canada the one-way disc has been used to cut through the common couch rhizomes and destroy top growth rather than dragging the couch out and spreading it around (Hardy, 1949). It may require one operation per week during the 6-week period when the couch rhizomes are being depleted of resources. The discs are operated at 2.5-3.5 cm deep to minimise damage to the soil structure.

Couch was controlled traditionally by cultivation, harrowing, raking and burning during fallow periods (Morse & Palmer,1925). It can be almost completely killed in one season by repeated cultivations that begin in spring (Håkansson, 1982). The optimum time for repetition of tillage is when regrowth has reached the 3-4 leaf stage (Håkansson, 2003). In a fallow period, progressively deeper spring-tine cultivations aim to bring rhizomes to the soil surface to be desiccated. Actively growing rhizomes are readily killed by desiccation when exposed to dry air for a few days at moderate temperatures (Low & Buchholtz, 1952). However, if covered even with a shallow layer of dry soil the rhizomes may survive. Moisture loss from the rhizomes must be greater than 80% to be effective (Cussans, 1972a). The best time to work the land is when the soil falls readily from the rhizomes. Rolling greatly assists the harrows in shaking off the soil (MAFF, 1949). Repeated cultivations are not good for a poorly structured soil but a full fallow should not be needed on light land.

In the north of England, the later and more protracted ripening of cereals favours couch and other rhizomatous grasses (Attwood, 1981). There is a long period after the cereal leaves dieback and before harvest when the canopy opens and couch can make good growth and build up reserves. After the later harvest there is usually only a short period for cultivations before the land becomes too wet to work. A rotation of continuous cereals leads to a steady increase in common couch (Pallutt, 1993).

In Norway, ridge fallowing was regarded as the most effective system of fallowing (Bylterud, 1965). After ploughing and harrowing the soil is laid up in large ridges 75 cm apart. When the couch grass shoots are 5 cm long the ridges are split with a plough. In this way some rhizomes dry out on the surface others are cut up and buried. The splitting is repeated 5-6 times at intervals of 10-20 days. Unfortunately ridge-fallowing is best performed with a one share broad plough. Some ploughs with multiple shares may not invert the soil fully leaving strips of couch grass visible between slices. Autumn fallowing has been used in Denmark when there is low precipitation and the cultivations after cereal harvest are used to bring couch rhizomes to the surface for drying out. However, if conditions are too dry couch growth ceases and soil tillage has no effect on the dormant rhizomes.

A bastard or half fallow can precede fodder or vegetable crops in spring or ploughing can be delayed following forage crop or early cereal harvest (MAFF, 1974). Vetches or a mixture of oats and vetches may be sown in autumn (or oats and peas in spring) for making into hay or silage. As soon as this crop is removed the land is ploughed and fallowed until autumn (MAFF, 1949). A short rotation including extra root or hoed crops is of value in combating couch. The use of a smother crop such as Lucerne or clover has sometimes proved effective (Salisbury, 1961).

In Denmark, a midsummer fallow followed by a catch crop gave a consistent reduction in couch and limited nutrient losses (Melander *et al.,* 2004; 2005). The fallow was started on 1st July by shallow ploughing to 10 cm followed by weekly tine cultivations until early August. At the end of the fallow the soil was ploughed to 20 cm and sown with a catch crop of red clover, fodder radish and winter rye. This gave over 90% control of the couch population. There was more variable control of couch when mechanical cultivation was carried out within 2 days of cereal harvest and a cover crop sown within a week of this. The reduction of couch emergence in the barley crop sown in spring was variable due to cold wet conditions overwinter and poor establishment of the cover crop. In general, the strategy gives around 40% control of the couch population.

In cropping systems without fallow periods, apart from repeated inter-row cultivation in row crops, the main period for couch control is after harvest. In cereals it is critical that rhizome fragmentation takes place as soon after harvest as possible (Barnes & Elliott, 1970). The aim is to stimulate dormant buds to grow and then destroy the resulting shoots (Sagar, 1960). A tractor mounted L-blade rotavator working to a depth of 15-cm is needed to cut the rhizome into short lengths (Fail, 1956). The first cultivation should cut rhizomes into 2.5-15 cm lengths many of which will perish or partially die back. Survivors will develop a new root and shoot at one node; a further rotavation 2-3 weeks later will kill many of these. Rotavation needs to be repeated when survivors have developed shoots 5-10 cm long (2-leaf stage). Allowing regrowth to remain beyond 15 cm tall (3-4 leaf stage) before reburial will replenish the food reserves and make control less effective. The number of cultivations needed to eradicate the weed varies between 2 on light friable soil to 6 on heavy clay. Cultivations may be repeated at 3-week intervals until winter sets in (Barnes & Elliott, 1970). A rotary cultivator has proved more effective than disks or rigid tine cultivators for breaking up the rhizomes. In Denmark, intensive stubble cultivations resulted in a decrease in couch populations in the year after treatment but the effect is lost after a further year unless the treatment is repeated (Rasmussen & Askegaard,

2004). Perennial weeds are traditionally controlled by stubble cultivations in the autumn after a cereal or pulse crop followed by ploughing in late autumn on a heavy soil or early spring on a light soil but this can result in nutrient losses (Rasmussen *et al.,* 2005a; 2005b). A catch crop can prevent nutrient loss but will limit stubble cultivations. Couch populations tend to increase in the presence of cover cover crops and absence of stubble cultivations.

In barley stubble, a single rotary cultivation in late-August/September reduced spring shoot emergence by 80% (Cussans & Wilson, 1970). A second cultivation, 3 weeks later when regrowth had 1-2 leaves, reduced spring emergence by 90%. In addition to the rotary cultivations, the land was ploughed, cultivated and drilled with spring barley. Common couch weakened by autumn cultivations is more susceptible to burial than an undisturbed stand (Cussans, 1972a). The treatment works best when conditions at the time of rotovation are good for stimulating bud growth on the rhizome fragments (Elliott *et al.,* 1966). A comparison between rotary cultivations in spring barley stubble aimed at fragmenting rhizomes and tined cultivations that shake rhizomes free of soil and allow them to desiccate on the soil surface suggested both were equally effective in reducing rhizome mass (Hughes & Roebuck, 1970). In Canada, repeated tillage from the beginning of August has given excellent couch control (Werner & Rioux, 1977). Rotary cultivations after cutting hay in July/August gave better control than disking and ploughing (Lowe & Buchholtz, 1952). In New Zealand, undersowing cereals with clover had no apparent effect on couch shoots. A summer fallow during which the soil was rotary hoed three times eliminated couch while a single rotary hoeing followed by a green feed crop did not (Popay & Stiefel, 1994).

Proctor (1960) found that the level of control of rhizomatous grass weeds with a rotary cultivator was limited by the machinery used. With a 'Howard Rotavator' towed by an underpowered tractor PTO speed was inadequate at a reasonable penetration depth. Even on a light silty soil the final depth was 10 cm while rhizomes had been ploughed down to 27.5 cm. A 'Selectatilth Rotovator' with a wider range of motor speeds and powered by a more powerful tractor gave deeper penetration although dry soil conditions made this difficult to achieve. Control was reasonable but more rhizomes were brought to the surface by deep ploughing to break up any soil pan that the rotovations may have produced. Rhizomes ploughed down to 35 cm are killed.

After a period of undisturbed growth the first deep tillage should invert the soil so that the upper layers where the majority of new rhizomes have developed will be buried (Håkansson, 1969a). Preceding this with shallow cultivations to break up the rhizomes will give the best results. Ploughing to 30 cm will bury foliage and rhizomes under 15-20 cm of soil (MAFF, 1974). The aim of deep burial is to cause activated buds to perish without establishing aerial shoots or to exhaust the rhizomes food reserves as it regrows to the soil surface. Vengris (1962) recommends cutting rhizomes into short lengths by cultivation, allowing shoots to grow to 5-7.5 cm then ploughing under to at least 15 cm. Repeated rhizome fragmentation without deep burial leads to an increase in the number of aerial shoots rather than greater rhizome production (Håkansson, 1968b). In a Norwegian study, infestations of the perennial common couch greater following shallow and less intensive tillage (Børresen & Njøs, 1994). The minimum capacity for recovery from burial was generally when rhizome

pieces had aerial shoots 12-15 cm long with 3-4 leaves and with new rhizomes and tillers about to develop (Håkansson, 1967; 2003). The food reserves in regenerating rhizomes are said to be lowest when developing shoots are at the 2-leaf stage (Cussans, 1972a). It was noted that couch infestations declined over a 3-year period in a field cropped with spring barley when a change of plough increased the depth of burial of the rhizomes (Scragg, 1981). Rhizome buds can remain viable for up to 30 months and 2-3 years of total control is needed to eradicate common couch (Lemieux *et al.,* 1993).

The rhizomes of couch infestations that develop in minimum tillage systems remain in predominantly in the upper 10 cm of soil (Lemieux *et al.,* 1993). Where autumn ploughing is practiced 68% of rhizomes are below the 10 cm soil layer and 19% are below 20 cm. Shoot emergence is more protracted where rhizomes are distributed through a greater depth of soil.

In an organic rotation improved nutrient supply increased cereal crop competitiveness against common couch but not sufficiently to control the weed (Olesen *et al.,* 2005). In long-term crop rotation experiments in Denmark, stubble cultivations in autumn decreased couch infestations but increased nitrate loss through leaching. Cover crops helped to retain the nutrients and improved yield in the cereals that followed but couch infestations increased.

Stubble cultivation before ploughing was the most effective way to reduce the amount of common couch when bringing a long-term ley to an end (Kakriainen-Rouhiainen *et al.,* 2003). It made little difference whether the land was ploughed in September, October or in Spring (Kakriainen-Rouhiainen *et al.,* 2004). A midsummer bare fallow treatment prior to ploughing reduced shoot numbers significantly in the following barley crop.

Cutting the aerial shoots from regenerating rhizome pieces at weekly intervals inhibited further rhizome production and may kill plants eventually but less frequent cutting was not successful. Cutting at soil level was more effective than at 2 cm above the soil surface. Defoliation of the shoots from regenerating rhizome fragments prevented new rhizome growth and exhausted the reserves in 7.5 cm fragments within 35 days (Turner, 1966). Rhizome fragments 11.3 and 22.5 cm long lost their reserves too but more slowly. Defoliation at 28-day intervals was not effective in preventing new rhizome growth. The addition of nitrogen fertilizer increased root and shoot growth and helped to reduce food reserves under frequent defoliation. The time of year has not been shown to be of importance in measures to deplete food reserves. In Sweden, defoliation repeated when regrowth reached a height of 2.5 cm prevented new rhizome formation (Håkansson, 1969c). Rhizome growth became less suppressed as cutting height was increased. In roadside verges, increased cutting frequency reduced the incidence of common couch (Parr & Way, 1984; 1988).

A strategy of post-harvest fragmentation and uprooting of common couch rhizomes followed by a suppressive cover-crop with a dense leaf canopy has given variable results depending on the successful establishment of the catch crop (Melander, 2006). Competition from the crop can enhance the control of couch weakened by burial or fragmentation but, in general, smother crops alone have less effect on couch growth than cultivations (Lowe & Buchholtz, 1952). Seedling development from common

couch seed sown in both spring and winter cereals was slow and few rhizomes were formed (Williams, 1972). Seedling growth was more vigorous in spring field beans and rhizome production was much greater. The lower light level in a spring oat crop is more likely to reduce couch growth than a spring wheat crop (Skuterud, 1984). Under-sowing with ryegrass or red clover reduced couch seedling growth in both spring barley and field beans. Common couch that regrew from rhizomes was suppressed more by spring barley and wheat than by spring field beans (Cussans, 1970). At low weed populations (45 shoots/yd^2) the cereal yield was not affected but higher weed numbers (180 shoots/yd^2) reduced yield by around 20%. Field bean yield was reduced by 43% and 79% by low and high couch populations respectively. Seedlings of couch were much more susceptible to competition from wheat than plants derived from single node rhizome pieces. The faster emergence and initial growth of the wheat seedlings reduced biomass of even the rhizome derived plants by 77% (Williams, 1973b). When the couch and wheat seedlings were grown alone, the later growth of the weed was much faster than that of the cereal mainly due to a greater leaf area (Williams, 1970b). Undersowing cereals and grain legumes with Italian ryegrass, red clover or a mixture of the two can retard the spread of couch grass (Lampkin, 1998; Williams, 1972, Cussans, 1972b). Establishment and early development of barley was consistently more rapid than couch (Cussans, 1968a). The early growth of regenerating couch was markedly suppressed by barley and by oilseed rape (Cussans, 1968b). The number of flower heads was also reduced. Field beans were much less competitive and wheat was intermediate in its ability to suppress couch. The main effect was to reduce light levels under the crop canopy. In the past in the UK, a field infested with couch would be put down to potatoes so that the scuffling, ridging and other operations both before and after crop emergence would reduce the weed.

Common couch may have so little effect on the yield of spring barley that control is not merited (Scragg & McKelvie, 1976). In field trials in Denmark, the competitiveness of 5 crops against common couch could be ranked: winter rye>winter wheat, spring barley>spring oilseed rape, peas, with rye the most competitive (Melander, 1993). Yield losses ranged from 8% for rye to around 35% in peas and rape at a density of 100 primary shoots of common couch per m^2. In cereals there was a linear relationship between crop yield and primary shoot density of common couch. In peas and oilseed rape the relationship was curvilinear.

In some grass fields uniformly infested with couch, there was a gradual decline in the occurrence of couch from three years after establishment until recording stopped in year ten. It has been said that if land is laid down to grass, couch will be eradicated in 2-3 years (Morse & Palmer, 1925). In perennial ryegrass swards, as the interval between cutting increased to more than 4 weeks, common couch rhizomes increased in dry weight (Courtney, 1980). The rhizomes grew better at higher nitrogen levels despite greater competition from the ryegrass at higher fertility levels. Cutting at intervals of 2 to 4 weeks is more likely to reduce couch levels than allowing 8 weeks between cuts. Rhizome growth also depended on the composition of the sward (Courtney, 1972). Tetraploid Italian ryegrass (*Lolium multiflorum*) and rough meadow-grass (*Poa trivialis*) was less competitive than perennial ryegrass (*L. perenne*) or cocksfoot (*Dactylis glomerata*). Common couch is relatively palatable and is absent from heavily grazed pasture (Grime *et al.,* 1988). In grassland grazed by

horses it is often associated with latrine areas (Gibson, 1996). Mowing a Timothy/red clover ley was not effective in reducing common couch (Vanhala *et al.,* 2003).

Competition suppressed the growth of common couch in headlands sown with grass or wildflower/grass mixes in comparison with unsown headlands (West et al., 1997). The ingress of the weed from the field margins was reduced but not prevented. 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 winter wheat cropped strip the boundary strips delayed the spread of common couch from the hedge into the field but did not prevent it. There was little difference between the boundary strip treatments.

Couch will not persist under a system of close grazing. If a suitable mixture of grasses and white clover is sown and efficiently managed for a few years the weed will be gradually suppressed (MAFF, 1949). Pigs in a moveable pen will root out and consume the rhizomes (Mitich, 1987). The rhizomes are also said to be relished by horses and cattle (Morse & Palmer, 1925). Geese will eat common couch and may be selective in certain crops (Quarles, 1999).

Common couch was not controlled by flame weeding and regenerated rapidly after treatment (Ivens, 1966; Bertram, 1997). An old method of controlling common couch was to light a series of small fires over an infested field. On heavy land this also had the effect of improving the soil texture.

In greenhouse tests, corn gluten meal (CGM) applied as a surface and incorporated treatment to soil has been shown to reduce plant development (Bingaman & Christians, 1995). The lowest rate of 324 g/m^2 had no effect on seedling survival but at 649 and 973 g/m^2 survival was reduced by 20 and 71% respectively. Root and shoot development of the survivors was reduced more by the incorporated treatment. Corn gluten hydrolysate (CGH), a water soluble material derived from CGM, was found to be more active than CGM when applied to the surface of pots of soil sown with common couch seed (Liu & Christians, 1997). Wheat gluten meal (WGM) at 1 or 3 $g.dm^{-2}$ dusted over seeds put to germinate on moist paper reduced germination by 37 and 50% respectively (Gough & Carlstrom, 1999).

Like many weeds, common couch often occurs in patches that may require different treatment from the rest of a field. Techniques have been developed for mapping the spatial distribution of couch to facilitate patch spraying of the weed with herbicide (Rew *et al*., 1996). It may be possible to use similar techniques to monitor weed spread and for treating weed patches using non-chemical methods. Mathematical models for the calculation of the rates of change in the size of weed infestations may be used to simulate weed management scenarios for common couch (Mortimer & Putwain, 1981).

Acknowledgement

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