The biology and non-chemical control of White Clover (*Trifolium repens* L.)

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White Clover

(Dutch clover)
***Trifolium repens* L.**

Occurrence

White clover is a procumbent perennial plant native in grassy and rough ground, common throughout Britain (Stace, 1997). It is the most abundant legume in British grassland (Turkington & Harper, 1979). It is recorded up to 2,400 ft (Salisbury, 1961). White clover is frequent on soils of pH 5.0 to 8.0 and is rarely found on peat (Grime *et al.*, 1988). It is common on clay soils (Clapham *et al.*, 1987). White clover can tolerate moderate treading (Bates, 1935). White clover establishes well in disturbed and open sites but is not shade tolerant (Weber, 2003). It is sensitive to drought and severe frosts. White clover is less tolerant of saline conditions than many of the pasture grasses.

White clover is widespread in pastures and meadows, frequently cut grass verges and lawns (Burdon, 1983). It is absent from tall grass. White clover is often associated with heavily grazed short swards (Gibson, 1996; 1997). It frequently occurs as seedlings on arable land. It is a common garden weed (Copson & Roberts, 1991). In unsown set-aside land in Scotland, white clover was the most frequently recorded species and comprised the second highest ground cover (Fisher *et al.*, 1992). In a study of seedbanks in some arable soils in the English midlands sampled in 1972-3, white clover was recorded in 59% of the fields sampled in Oxfordshire and 53% of those in Warwickshire but only in low numbers (Roberts & Chancellor, 1986). White clover seed was found in 9% of arable fields in a seedbank survey in Scotland in 1972-1978 (Warwick, 1984). In a seedbank survey in swede-turnip fields in Scotland in 1982, it was found in 37% of the fields sampled (Lawson *et al.*, 1982). In a survey of seeds in pasture soils in the Netherlands in 1966, white clover was common in the sward and in the soil seedbank (Van Altena & Minderhoud, 1972).

White clover is a highly variable species with many varieties and over 70 commercial cultivars (Weber, 2003; Burdon, 1983). Traditionally, much of the seed of cultivated white clover has been imported from Holland, Czechoslovakia, Poland and more recently Canada and New Zealand (Burdon, 1983). Native strains, referred to as wild white clover are considered more desirable than the so called Dutch clovers (Tansley, 1949). White clover increases soil fertility through the presence of nitrogen fixing bacteria in nodules on the roots. It plays a key role in the nitrogen economy of many grassland communities (Turkington & Harper, 1979). White clover has been an important constituent of fodder since the 17th century and is the most important pasture legume in Britain (Grime *et al.*, 1988). The foliage is generally palatable to grazing animals but some genotypes contain cyanogenic glucosides that, when consumed in quantity, can disrupt the rumen of domestic livestock. White clover has a relatively high calcium content (Wilman & Riley, 1993). It is an important source of winter food for wildfowl (Burdon, 1983).

White clover can carry economically important virus diseases some of which are seed borne (Heathcote, 1970). The potato tuber rot nematode, *Ditylenchus destructor*, can infest it too (Franklin, 1970).

Biology

White clover flowers from June to September (Clapham *et al.*, 1987) but mostly in June and July (Grime *et al.*, 1988). The flowers are mainly insect pollinated and outbreeding. Selfed individuals set very few seeds. Seeds start to become viable after 12 days. The hard coated seeds take a month to fully ripen and there are 3-6 seeds per pod. The 1,000 seed weight ranges from 0.5 to 0.8 g (Burdon, 1983). For clover grown as a commercial seed crop the yield of seed varies with the cultivar and the growing conditions and ranges from 13 to 151 kg per ha.

The germination of fresh seed is not promoted by light (Wesson & Wareing, 1969). Scarification increased the level of seed germination from 21 to 99% (Grime *et al.*, 1981). Germination of scarified seed was uniformly high at alternating and constant temperatures in darkness and under a safe green light. Seed sown in a 75 mm layer of soil in cylinders sunk in the field and stirred periodically, emerged mainly from March to May with odd seedlings emerging throughout the year (Roberts & Boddrell, 1985). Most seedlings emerged in the first 2 years of the 5-year experiment but emergence continued till year 5 when a few viable seeds still remained. Field emergence in plots cultivated at monthly, 3 monthly or yearly intervals or not at all extended from March to November with no real peaks (Chancellor, 1964). In plots dug into a grass sward and cultivated at monthly intervals, white clover seedlings emerged from February to September with a peak between March and May (Chancellor, 1986). Although white clover seed may be at a high density in the soil beneath permanent pasture, seedlings are rare (Turkington *et al.*, 1979). Seedlings occur mainly where there are local areas of soil disturbance such as molehills. Fewer than 1% of seeds sown into an undamaged sward produce seedlings while 40% of seeds sown in denuded areas produce seedlings.

In a sandy loam soil, field seedlings emerged from the top 0 to 30 mm of soil with most from the surface 20 mm (Unpublished information). Clover plants begin to produce stolons 7 weeks after seedling emergence (Turkington & Cavers, 1978). The stolons initiate adventitious roots at the nodes almost immediately. Stolons can be 50 cm long (Burdon, 1983). However, in an open situation the main stolon can reach a length of 95 cm while in crowded conditions the length is 38 cm (Kershaw, 1959). The stolons branch through the development of axillary buds and these then develop secondary branches. After 2 or more years the connection between the primary stolon and the parent rots away. It has been suggested that as white clover is susceptible to shade the creeping habit allows it to move from areas with low light levels into more favourable ones.

Vegetative growth tends to begin in April and reaches a maximum in June-August. Plants may flower in the first year of growth but clones vary in their capacity to flower freely. Many clones produce few or no flowers others contribute a disproportionate amount to the seed output (Turkington *et al.*, 1979).

Persistence and Spread

White clover seed that has not been subjected to abrasion either from mechanical harvesting or soil cultivation has a high proportion of impermeable seeds and is more likely to remain dormant (Hyde & Suckland, 1953). An appreciable seedbank can develop in the soil under grassland where white clover is allowed to flower and set seed (Roberts, 1981). In New Zealand, pasture soils grazed by sheep contained fewer seeds in the seedbank than pasture grazed by cattle. Ungrazed pasture used as a seed crop had the highest seed numbers in the soil. In a 10-year old neutral grassland, white clover was common in the vegetation cover and in the soil seedbank (Thompson *et al.,* 1994). In other studies, white clover seeds have been recorded in enormous numbers in the soil beneath pastures even though the plant was poorly represented in the vegetation (Champness & Morris, 1948).

Commercial seed retained only 4% viability after 1 year of soil burial but some seeds were still viable after 5 years (Kjaer, 1940). In Beale's burial experiment, seed buried in soil did not germinate after 5 years (Crocker, 1938). In Duvel's burial experiment, seed buried at 20, 55 and 105 cm gave sporadic germination of up to 5% over the first 30 years (Toole, 1946; Goss, 1924). Seed buried in mineral soil at 13, 26 or 39 cm depth and left undisturbed retained 6 to 23% viability after 1 year, 5 to 7% after 4 years and 1% after 20 years (Lewis, 1973). Seed buried in a peat soil at 26 cm retained 7, 6 and 2% viability after 1, 4 and 20 years respectively. Seed stored under granary conditions after 1, 4 and 20 years retained 88%, trace and nil viability respectively. Under dry storage the seed gave 55% germination after 5 years (Kjaer, 1940).

Although white clover may be well represented in the soil seedbank beneath pasture it often perpetuates by vegetative means (Chippindale & Milton, 1934). Where seeding is prevented, white clover can survive almost entirely through vegetative reproduction (Hyde & Suckland, 1953). The creeping shoots root at the nodes and can form a large clonal patch (Clapham *et al.,* 1987; Grime *et al.,* 1988). Clones differ in aggressiveness but a mixture of different clones often yields better than a single clone (Turkington *et al.,* 1979). Plant longevity is difficult to estimate but clones are known to have survived in situ for over 60 years (Burdon, 1983).

Seed is important for the colonization of new habitats. Apparently-viable seed has been found in samples of cow manure (Pleasant & Schlather, 1994). White clover was the most numerous seed to survive in dairy farm manure that had been composted (Bilodeau *et al.,* 1999). In Australia, large numbers of seeds have been found in cattle droppings (Jones, 1982). Up to 108 seeds per g have been recorded. Seed numbers in the soil under the pasture were also considerable. Seeds survived passage through sheep, most were destroyed after 3 months in a dung heap but 5% remained viable (Özer, 1979). Viable seeds have been recovered from worm casts (Thompson *et al.,* 1994; McRill & Sagar, 1973; McRill, 1974). Passage through the earthworm's digestive system increased the germination of both hard-coated and non-hard-coated seed.

Management

White clover is tolerant of heavy grazing, trampling and cutting (Grime *et al.,* 1988). Frequent and intense grazing encourages the growth of white clover (Weber, 2003, Blackman, 1933). White clover decreases under lenient spring grazing and increases under tight spring and autumn grazing by sheep (NERC, 2006). Cultivars with thick,

profuse stolons are better able to recover and make quicker regrowth after grazing. Small leaved cultivars survive better under intense sheep grazing as they have a creeping habit. Large leaved cultivars are high yielding but less persistent under grazing and are best in hay or silage swards. Medium leaved varieties are generally tolerant of a wide range of conditions. A mixture of cultivars will often give the best results.

In undergrazed pasture white clover is suppressed by the taller growing grasses (Kydd, 1964). Conditions that favour grasses lead to a decrease in white clover (Blackman, 1933). The peak period of active growth for white clover occurs in late June-July (Turkington & Harper, 1979; Blackman, 1933). The time of grazing can have an effect on white clover growth (Burdon, 1983). Heavy grazing of a white clover/perennial ryegrass sward in March, April and May leads to a substantial increase in white clover at the expense of the grass. Grazing after April leads to a decline in the white clover but not the ryegrass. The frequency and intensity of grazing may also affect the relative balance of different clones or cultivars of white clover within a field. The highly selective nature of sheep grazing can have a differential effect on white clover clones. The leaves of different cultivars often have characteristic white marks and sheep have shown a distinct bias towards particular markings. High stocking rates on grassland can cause a shift in species composition in favour of white clover and perennial ryegrass because of their resistance to trampling (Burdon, 1983). Undergrazing is responsible for a decline in white clover (Blackman, 1933).

In pasture the success of white clover depends on the composition of the vegetation as the legume occupies the same niche as many other dicotyledonous herbs as well as the grasses (Turkington *et al.*, 1979). It grows less well in swards dominated by Yorkshire-fog (*Holcus lanatus*) or common bent (*Agrostis capillaris*) than those with perennial ryegrass (*Lolium perenne*). In grassland, pattern analysis shows that white clover is positively associated with perennial ryegrass (Turkington & Harper, 1979). It does not occur with cock's-foot (*Dactylis glomerata*) and abundance is negatively correlated with the concentration of magnesium in soil.

In roadside verges, increased cutting frequency increased the incidence of white clover (Parr & Way, 1988). In grass-clover swards, infrequent cutting, 3 times per year, leads to domination by the grass (Burdon, 1983). Frequent cutting, 6 times per year, allows the white clover to dominate the sward.

Seeds of *Trifolium* species were not killed by field steaming treatments applied by mobile steamer (White *et al.*, 2000).

In Suffolk, it has been noted that during the winter wood pigeons feed almost exclusively on white and red clover leaves (Burdon, 1983). At this time they may consume 50% of the clover in the pasture. White clover loses much of its seeds to pre-dispersal predation by grazing animals and rabbits eating the flowers (Turkington *et al.*, 1979). White clover tolerates rabbit grazing but growth becomes more prostrate (Gillham, 1955). Clover in grassland is susceptible to attack by leatherjackets but usually recovers. A number of insects and their larvae feed on the roots, leaves and seeds of white clover (Burdon, 1983). Slugs and snails also graze

the plants. Fungal pathogens infect white clover particularly in the colder months of the year.

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