

The biology and non-chemical control of Annual Meadow-grass (*Poa annua* L.)

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Annual meadow-grass

(annual bluegrass, cause-way grass, Suffolk grass, spear grass)

***Poa annua* L.**

Occurrence

Annual meadow-grass is a native grass, generally an annual or short-lived perennial, common throughout the UK. It is typically a summer annual but can behave as a winter annual (Grime *et al.*, 1988). Annual meadow-grass is recorded up to 3,900 ft in Britain (Salisbury, 1961). In early studies in Bedfordshire, Hertfordshire and Norfolk it occurred on all types of soil but chiefly on loam and sandy loam, rarely on chalk (Brenchley, 1911; 1913). It does not thrive on acid soils and those low in phosphate. Multiple regression analysis of field distribution of annual meadow-grass indicates that it is favoured by increased organic matter in soil probably due to the greater water holding capacity (Andreasen *et al.*, 1991). It is sensitive to drought and high temperatures but is tolerant of compacted and poorly aerated soils (Warwick, 1979; Mitich, 1998). Annual meadow-grass can withstand periods of waterlogging and temporary flooding (Hutchinson & Seymour, 1982). It is characteristically found in open habitats but can endure some shading. An abundance of annual meadow-grass is indicative of high levels of nitrogen. It is a pioneer species and is characteristic of disturbed or unstable habitats. Annual meadow-grass populations tended to increase with the use of hormone herbicides that reduced competition from broad-leaved weeds.

Annual meadow-grass is a troublesome and ubiquitous weed on arable land, grassland, in gardens and on trackways (Clapham, *et al.*, 1987; Copson & Roberts, 1991). It is a relatively small plant but is often present in sufficient quantities to smother crop seedlings. It is often associated with heavily-grazed grassland (Gibson, 1997). Annual meadow-grass is regarded as a grassland weed because of its persistence, low growth habit and low productivity. It tends to be less digestible than perennial ryegrass (*Lolium perenne*) (Wilman & Riley, 1993). In a survey of grassland weeds, annual meadow-grass was found in small quantities in a high proportion of fields, particularly on disturbed ground around gateways and drinking troughs (Peel & Hopkins, 1980). It was present in young swards where establishment had been poor, in swards where Italian ryegrass was dying out after 3-4 years and in older swards damaged by poaching. Another survey showed that annual meadow-grass was one of the main weeds occurring in young swards, accounting for up to 20% of the composition (Wells, 1974a). In established pastures, ingress follows intensive grazing.

Annual meadow-grass is a weed of spring and autumn-sown crops (Jensen & Andreasen, 1993). It is shade tolerant and survives and sets seed in many crops. In a survey of weeds in conventional cereals in central southern England in 1982, annual meadow-grass was found in 14, 13 and 15% of winter wheat, winter barley and spring barley respectively (Chancellor & Froud-Williams, 1984). Annual meadow-grass was

one of the most frequent weed species present in conventional sugar beet crops surveyed in East Anglia in autumn 1998 (Lainsbury *et al.*, 1999). It was also a common species in the field margins. In a survey of UK cereal field margins recorded as part of Countryside 2000, annual meadow-grass was one of the most frequent species recorded (Firbank *et al.*, 2002). Annual meadow-grass remained widespread in the period between 1978 and 1990 despite increased herbicide use (Firbank, 1999). In unsown set-aside land in Scotland, annual meadow-grass was the most frequently recorded grass and of the grasses had the second highest ground cover (Fisher *et al.*, 1992). However, its frequency in the vegetation cover decreased between the first and third years in set-aside under natural regeneration in southern England (Wilson, 1992). It is a common weed in fruit tree plantations. A comparison of weed surveys of spring barley made in Denmark in 1970 and 1989 showed that the frequency remained unchanged despite extensive herbicide use (Streibig *et al.*, 1993). In a survey of weed populations in pasture soils in the Netherlands in 1966, annual meadow-grass was the most frequent species recorded (Van Altina & Minderhoud, 1972).

In a study of seedbanks in some arable soils in the English midlands sampled in 1972-3, annual meadow-grass was recorded in all of the fields sampled in Oxfordshire and Warwickshire sometimes in large numbers up to 35,550 seeds per m² (Roberts & Chancellor, 1986). Annual meadow-grass seed was found in 22% of arable soils in a survey in Scotland in 1972-1978 (Warwick, 1984). It accounted for 5% of the seeds in the soil seedbank. In a study of seedbanks of arable soils in Denmark in 1964 and 1989, viable annual meadow grass seeds represented 8.5% of the seedbank in 1964 and 20.5% in 1989 (Jensen & Kjellsson, 1992). The average number of viable seeds was 3,688 per m² (Jensen, 1969). It was also the most abundant grass weed in a seedbank survey in swede turnip fields in Scotland in 1982 (Lawson *et al.*, 1983). It was found in 89% of fields sampled. Annual meadow-grass is one of the most frequent arable weeds in Denmark and is well represented in the soil seedbank (Streibig, 1988).

Annual meadow-grass is a very adaptable species and many ecotypes have been recognised (Wells, 1974a). As a general rule it is self-pollinating but it has been suggested that up to 15% out-crossing can occur. Many named varieties and subspecies are recognised and there have been several attempts to describe the taxonomy of the species. There are indications that genotypic as well as phenotypic differences exist. Morphologically distinct races differ in speed of germination, growth habit and life span. Biotypes with resistance to the herbicides paraquat and simazine have been reported in hop gardens in Kent where there had been long-term use of the chemicals for weed control (Clay, 1989). Elsewhere, populations have been found with resistance to the herbicide aminotriazole (Putwain & Mortimer, 1989).

Both annual and perennial forms of annual meadow-grass have been reported (Mitich, 1998). Annual forms have erect growth while perennial ecotypes form a mass of tillers, some of which grow horizontally and root at the nodes (Wells, 1974a; Stace, 1997; Warwick, 1979). Perennial forms continue to tiller prior to overwintering. A perennial form of annual meadow-grass, *P. annua* var. *repens*, has been bred for use in lawns and sports turf (Fowler, 2004). Marketed under the name 'Tru Putt' it is highly stoloniferous and forms a dense, tread-resistant stand.

Annual meadow grass is very sensitive to air pollution (Wells, 1974a). The plant is easily damaged by atmospheric pollutants like smog and ozone and has been considered for use in pollution monitoring studies (Hutchinson & Seymour, 1982).

Annual meadow-grass is an important constituent in the diet of many farmland birds (Lainsbury *et al.*, 1999). In field headlands, annual meadow-grass is a useful food plant for gamebirds (Boatman & Sotherton, 1988). Ground beetles feed selectively on the seeds of annual meadow-grass (Norris & Kogan, 2000).

The grass can be the host of a number of nematode species that also attack important crop species (Thurston, 1970). Annual meadow grass can be infected with ergot and in cereals can act as a source of crop infection throughout much of the year (Blake, 2005). The fungal fruiting bodies are smaller and less obvious on a grass flower panicle than on a cereal ear.

Biology

Annual meadow-grass begins to flower in early spring and it continues through the growing season. Flowering is independent of daylength and can occur at any time through the year. Plants are self-compatible and seed set is high (Ellis, 1974). Up to 15% out-crossing occurs in natural populations. Flowers are wind and self-pollinated (Grime *et al.*, 1988). Cleistogamy is frequent in winter. Seed is produced abundantly from April to September and beyond. However, temperatures above 25°C are said to hinder anther development and prevent seed production. Annual meadow-grass inflorescences severed from the plant on the day of pollination are able to ripen viable seed (Lush, 1988a; Hutchinson & Seymour, 1982). Even in short turf it can flower and set seed (Lush, 1988b). Annual meadow-grass can be found in fruit throughout the year (Salisbury, 1962). Annual forms die after flowering and the vacant area is colonised by new seedlings (Warwick, 1979).

Viable seed number per inflorescence has been estimated at 80 seeds. Seed numbers per plant averaged 2,050 and the 1,000 seed weight was 0.20 g (Stevens, 1957). The average seed number per plant in ruderal situations is given as 2,251 (Pawlowski *et al.*, 1967). Several generations may be produced in a year. The perennial forms are said to produce 13,000 seeds per plant (Mitich, 1998). Even plants mown to 0.5 cm can produce 360 seeds per plant.

A high proportion of seed will germinate soon after it is shed. Annual meadow-grass normally germinates in late summer or early autumn from seed produced a month or so earlier. Germination occurs over a wide range of constant and alternating temperatures in the light. A proportion of freshly collected seeds exhibit dormancy. Seeds shed early appear to be more dormant than those that mature later (Froud-Williams, 1985). A tendency towards dormancy is associated with seed of annual forms. Populations in warmer climates have been shown to develop different requirements for dormancy breaking as an adaptation to local conditions (Standifer & Wilson, 1988a; 1988b). In the field, seedling numbers usually represent less than 6% of the number of viable seeds present in the soil seedbank (Roberts & Ricketts, 1979). The percentage tended to be higher when cultivations were closely followed by rainfall.

Large differences have been found in the germinability and mean germination time of seed from different populations of annual meadow-grass (Naylor & Abdalla, 1982). A germination value for one population may not be representative of other populations. Both freshly collected and dry-stored seed had a light requirement for germination (Froud-Williams *et al.*, 1984). However, in laboratory tests, dry-stored seed germinated to over 90% in constant or alternating temperatures with and without light (Wagenvoort & Van Opstal, 1979). There was a decrease in germination at constant temperatures below 10°C and above 20°C but not at alternating temperatures of 5/25°C (Froud-Williams, 1985). A rise in the amplitude of temperature fluctuations increased germination in both the light and dark up to an amplitude of 20°C (Thompson & Whatley, 1983). There was a decrease when the change was 25°C. In a laboratory study, chilling for 7 days in the dark or 4 days in the light achieved the maximum effect in relieving seed dormancy (Roberts & Benjamin, 1979). There was no re-induction of dormancy if chilling was continued beyond this period. Light and nitrate stimulated germination both before and after chilling. In Petri dish tests with seed maintained under high or low light intensity or in darkness, seed germinated completely in the light but only to 81% in the dark (Grime & Jarvis, 1976).

Seed sown in pans of field soil showed no periodicity of emergence. Most seeds germinated immediately but odd seedlings continued to emerge over the next 2 years (Brenchley & Warington, 1930). With seeds mixed in a 75 mm layer of soil in cylinders in the field and stirred 3 times per year, the main period of emergence was March to October. Emergence was greatest in year 2 at 17% with 8% in year 1 and 11% in year 3. Field emergence from plots cultivated at monthly, 3 monthly or yearly intervals or not at all, extended from February to November with a small peak in March & a larger one in Aug-Oct (Chancellor, 1964). Seed sown in a 75 mm layer of soil in cylinders sunk in the field and stirred periodically, emerged intermittently from February to November (Roberts, 1964). In a later study, the main period of emergence was March to October (Roberts, 1986). In plots dug into a grass sward and cultivated at monthly intervals, annual meadow-grass seedlings emerged all through the year with peaks in April, July-August and October (Chancellor, 1986). Seedling emergence in Scotland recorded in field plots dug at monthly intervals began in April and continued through until October (Lawson *et al.*, 1974). In a sandy loam soil, field seedlings emerged from the top 20 mm of soil with the majority emerging from the upper 10 mm and up to 88% in the surface 5 mm (Unpublished information).

Annual meadow-grass seed sown at intervals germinated at most times of year, although number and rate of emergence was affected by weather conditions (Wells, 1974b). Seeds took around 20 days to achieve 50% emergence when moisture was adequate but dry conditions delayed emergence in the summer months. Shortly after emergence the young seedlings develop adventitious roots that form the bulk of the root mass of mature plants. Plants that develop early in the year generally grow larger and produced more tillers than those emerging later. Plants that emerge from August to December overwinter and begin to tiller in spring. These plants flower in May-June. Spring emerging seedlings flower in July-September. Plants that became established in summer began flowering at an earlier growth stage and had smaller panicles. Two ecotypes were identified, one had an average longevity of 13 months the other lived 19 months.

A simple seed population dynamics diagram for annual meadow-grass has been constructed based on data from a study where seed was scattered on plots that had been deep cultivated, surface cultivated or left as a closed sward cut to 75 mm (Mortimer, 1976). Seed was found to have a 90% viability and, being small, soon became incorporated in the surface seedbank. Invertebrate activity and greater openness at the soil surface increased the chance of seed burial. Only 7% of the seed produced seedlings and less than 8% of these reached maturity. Excluding the invertebrates increased the number of seedlings that survived. By estimating the age-specific survival from seedlings to mature plants, a model can predict the potential size of future annual meadow-grass populations (Mortimer *et al.*, 1978). The consequences of different weed control operations on the population can also be explored.

Studies of colonization by annual meadow-grass demonstrated that after a short period of increasing plant numbers the population stabilised at 4,500 plants/m² (Law, 1981). There were slight seasonal fluctuations with peak densities in spring and autumn following greater recruitment of seedlings at this time. The population was made up of recently emerged seedlings and plants up to about 20 months old. Plants begin to flower from around 1 month after emergence but flowering is much less prolific as plant density increases. The mean number of seeds per inflorescence was 62 but this decreased with increasing plant density. A tiller that produces seed almost always dies.

In Petri-dish tests, water extracts from plant residues of annual meadow-grass inhibited the germination of clover, lettuce and radish but not wheat seed (Carley & Watson, 1968). The root growth of the wheat seedlings, however, was considerably reduced.

Persistence and Spread

Thompson *et al.* (1993) suggest that based on seed characters, annual meadow-grass seed should persist for longer than 5 years in soil. Annual meadow-grass can form a major proportion of the seeds in the seedbank of both arable and grassland soils (Wells, 1974a; Roberts, 1986). The seed can remain viable in soil for at least 4 years. Seed losses are greater in cultivated soil. Seeds mixed with soil and left undisturbed had declined by 76% after 6 years but in cultivated soil the decline was 92% (Roberts & Feast, 1973b). Seedbank decline was studied in a succession of autumn-sown crops (winter wheat & winter OSR) in fields ploughed annually with seed return prevented (Lawson *et al.*, 1993). Time to 99% decline was calculated at 4.3 years with a mean decline per year of 55%. In naturally-occurring populations of weed seeds in undisturbed soil, the annual loss was 46% (Roberts & Feast, 1973a). Dry-stored seed still had 98% viability after 3 years (Rampton & Ching, 1970).

Large seedbanks of annual meadow-grass occur in pastures and turf (Lush, 1988b). 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). There is a transient and a persistent component to the seedbanks. The persistent seeds are those buried deeper in the soil and these can be relatively long-lived. In Belgium, annual meadow-grass was one of the main species that remained in the seedbank of a reclaimed heath that was under arable cropping since 1924 and under grassland from the 1960s (Stieperaere & Timmerman, 1983). In a study of the

impact of set-aside on the soil seedbank, annual meadow-grass which had formed a major component of the seedbank under arable cropping, formed an even larger proportion of the seeds after 3 years under set-aside (Lawson *et al.*, 1994). There was some increase when there was a sown grass cover but it was greater when the set-aside was left fallow (Lawson *et al.*, 1992). Seed numbers also increased following establishment of leys (Roberts & Chancellor, 1986).

Annual meadow-grass is a prolific seed producer but there is no obvious dispersal mechanism and most seed falls around the parent. When the seeds were ingested by earthworms, around 25-28% were recovered intact and viable in wormcasts (McRill, 1974). In the field, over 100 seeds were found in 100g of wormcast soil. Seeds were found in 9% of worm casts collect on a neutral grassland (Thompson *et al.*, 1994). While not an effective method of dispersal, seeds brought to the soil surface in wormcasts may find conditions more favourable for germination. Annual meadow-grass will also colonise molehills before being replaced by perennial grasses. The seeds are readily transported in mud by vehicular and foot traffic. Mowing also spreads the seeds. Seeds of annual meadow-grass floating on water have been observed to travel by wind power across the surface (MacNaeidhe & Curran, 1982). Viable seeds have been found in cattle dung (Pleasant & Schlather, 1994) but viability is lost after a period of manure storage (Wells, 1974a). Seed has been found in cattle and horse droppings (Salisbury, 1961), also in deer droppings (Hutchinson & Seymour, 1982).

Annual meadow-grass seed is a common contaminant of crop seeds. In samples of perennial ryegrass seed of English origin tested in 1960-61, annual meadow-grass was the most frequent weed species being found in 23% of samples (Gooch, 1963). High numbers were also present in seed samples of Irish origin, and in samples of Italian ryegrass, cocksfoot, timothy, meadow fescue, tall fescue and red fescue. Annual meadow-grass was also found in 4% of celery seed samples tested. In samples of cultivated grass seed tested for purity in 1967 by the Official Seed Testing Station, Cambridge, annual meadow-grass seed was a frequent contaminant in seeds of Danish and Irish, Danish and Swedish origin (Tonkin, 1968). In clover and grass seed tested in Denmark for the period 1966-1969, annual meadow-grass was the most frequent contaminant being found in around 50% of samples (Olesen & Jensen, 1969). In Italian ryegrass seed there was an average of 435 annual meadow-grass seeds per kg of ryegrass seed and a maximum of 8,625 seeds per kg. In clover and grass seed samples tested in the periods of 1955-57, 1939 and 1927-28, annual meadow-grass seed was a contaminant in 23.7, 10.1 and 8.8% of samples respectively. In a survey of weed seed contamination in cereal seed in drills ready for sowing on farm in spring 1970, it was found in 5% of samples (Tonkin & Phillipson, 1973). Most of this was home saved seed. In the period 1978-1981, it was found in 1-5% of wheat and 7-10% of barley seed samples tested (Tonkin, 1982).

Perennial forms can spread vegetatively by creeping rooted stems but this is very limited (Grime *et al.*, 1988).

Management

Ploughing and other tillage operations do much to keep annual meadow-grass in check (Morse & Palmer, 1925). Control is by surface cultivation to encourage germination followed by harrowing to kill the emerged seedlings (Long, 1938). In

root crops, hoeing keeps the weed contained. In experiments over 9 years using different primary cultivations in a vegetable crop rotation it was noted that the different regimes had a pronounced effect on seed numbers of annual meadow-grass (Roberts, 1965). At the end of the experiment, seed numbers were 7, 11 and 23 million per acre respectively for deep ploughed (35-40 cm), shallow ploughed (15-18 cm) and rotary cultivations (15-18 cm). In a comparison of different tillage regimes in winter cereals, annual meadow-grass was favoured by reduced cultivations (Pollard & Cussans, 1981). In winter cereals, annual meadow-grass populations increased annually on direct drilled land but declined slightly after ploughing (Cussans *et al.*, 1979). In an experiment to determine seedbank changes under a mixed stand of weeds, seed numbers of annual meadow-grass in soil decreased from 4,200 to 1,150 /m² despite some seed shedding by plants that emerged following cultivation in April (Leguizamon & Roberts, 1982). Competition from the broad-leaved weeds prevented seed development by the grass. Seedlings of annual meadow-grass were less frequent in cereal crops on drained land than on land that had not been drained (Froud-Williams, 1982). Annual meadow-grass increased during conventional arable cropping over an 11-year period due to its tolerance of the herbicides used (Chancellor, 1976). However, some climatic or other factors may also be involved.

In permanent grassland, annual meadow-grass was favoured by fertilizer application (Williams, 1985). Both percentage cover and seed numbers in the soil increased. Annual meadow-grass can tolerate severe defoliation both from close grazing and mowing (Hutchinson & Seymour, 1982). Higher populations are found in turf cut to a height of less than 2 cm compared with a cutting height of 7.6 cm. It is still able to flower and set seed when cut regularly to a height of 0.65 cm. It is one of the most wear resistant of turf grasses. Overgrazing allows annual meadow-grass to invade grassland (Blackman, 1933). Under severe grazing, annual meadow-grass will soon appear and within 5 years it can make up a significant proportion of the sward (Spedding, 1966). Annual meadow-grass is tolerant of trampling, grazing and mowing (Grime *et al.*, 1988). Regular mowing and grazing cause increased branching. Within the mat of short stems, flowers are produced that set seed below cutting height.

Studies of the effect of physical damage on annual meadow-grass control showed that cutting seedlings at or below the soil surface was more effective than partial burial (Jones *et al.*, 1995). Complete burial, alone and after pulling seedlings out, was the most consistently effective treatment. There was the potential for recovery if seedlings were left on the soil surface or if just the roots were buried. Seedlings have fibrous roots and are easily dislodged by harrowing and other cultivations (Jensen & Andreasen, 1993). Larger plants are able to survive uprooting and may continue to ripen seeds on developed panicles (Hutchinson & Seymour, 1982). After crop harvest, ploughing buries with freshly shed seeds but this may lead to a future weed problem.

A simple lifecycle based demography model has been adapted to help in developing threshold-based weed management strategies for annual meadow-grass (Munier-Jolain *et al.*, 2002). Although intended for chemical control measures it could form the basis for a non-herbicide system. In experiments to determine economic threshold populations for annual meadow-grass in wheat it was observed that development of the weed was suppressed by a vigorous wheat canopy and competition from

broadleaved weeds (Woolley & Sherrott, 1993). The calculated economic threshold for chemical control was 714 plants per m² but this can be modified by climatic conditions and is also likely to be different for non-chemical control.

Seed numbers of annual meadow-grass in soil do not decrease and may increase following a fallow period (Brenchley & Warington, 1936). Seedlings that emerge in the autumn are able to grow and set seed before soil cultivations begin in spring.

The addition of farmyard manure, compost or sewage sludge to arable soils increased the frequency of annual meadow-grass (Mann, 1957). In laboratory tests, leachate from composted household waste decreased the germination of annual meadow-grass seed (Ligneau & Watt, 1995). In pot tests, covering the seeds with up to 3 cm depth of compost reduced seedling emergence but so did covering with soil. In greenhouse tests, corn gluten meal (CGM) applied as a surface and incorporated treatment to soil sown with annual meadow-grass seed has been shown to reduce seedling development (Bingaman & Christians, 1995). Application rates of 324, 649 and 973 g per m² reduced annual meadow-grass survival by 60, 81 and 72% respectively. Shoot length was reduced by up to 51%, root growth by up to 95%. 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 annual meadow-grass 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 99 and 100% respectively (Gough & Carlstrom, 1999).

Annual meadow-grass seedlings with 2-6 leaves are tolerant of flame weeding because the growing point is protected by leaves (Ascard, 1998). In studies to assess the use of UV radiation for selective weed control, annual meadow-grass was relatively tolerant at both the 4-leaf and 20-leaf stage (Andreasen *et al.*, 1999). In the USA, seeds of annual meadow-grass were killed down to 6 cm by soil solarization for 40 days under clear polyethylene sheeting (Standifer *et al.*, 1984). The germination of seeds in pots of moist soil heated with warm air for 6 hours was reduced by 50% at 47°C and 80-100% at 49°C (Laude, 1957).

Phytoparasitic bacteria have been considered as potential biological weed control candidates for annual meadow-grass. Spray applications of *Xanthomonas campestris* pv. *poannua* during mowing controlled annual meadow-grass (Johnson *et al.*, 1996). It failed to have an effect though when the grass was undamaged. Weekly applications over a few weeks should give a gradual conversion from annual meadow-grass dominated turf to more desirable turf species (Mittra *et al.*, 2001). The bacterium has a restricted host range and does not cause disease in desirable turf grasses. A number of other bacteria, fungi and insects are recorded on annual meadow-grass (Hutchinson & Seymour, 1982).

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