

The biology and non-chemical control of rushes (*Juncus* spp.)

W Bond, G Davies, RJ Turner

HDRA, Ryton Organic Gardens, Coventry, CV8, 3LG, UK

Blunt-flowered rush	<i>Juncus subnodulosus</i> Schrank (<i>J. obtusifolius</i>)
Compact rush	<i>J. conglomeratus</i> L. (<i>J. communis</i> var <i>conglomeratus</i>)
Hard rush (wire rush)	<i>J. inflexus</i> L. (<i>J. glaucus</i>)
Heath rush	<i>J. squarrosus</i> L.
Jointed rush (shining-fruited rush)	<i>J. articulatus</i> L. (<i>J. lampocarpus</i>)
Slender rush (North American rush)	<i>J. tenuis</i> (<i>J. macer</i>)
Sharp-flowered rush	<i>J. acutiflorus</i> Ehrh. Ex Hoffm. (<i>J. sylvaticus</i>)
Soft rush (common rush)	<i>J. effusus</i> L. (<i>J. communis</i> var. <i>effusus</i>)
Toad rush (frog grass, saltweed)	<i>J. bufonius</i> L. (<i>J. minutulus</i>)

Occurrence and biology

Rushes occur mainly but not solely on poorly drained soils of low pH. In flat pastureland on a heavy soil that is often waterlogged, rushes almost always occur (Tansley, 1949b). Only a few of the 25 or so British species are of importance as perennial weeds of pasture (ADAS, 1972). Some have a spreading habit others are tuft forming (Salisbury, 1961). There are species with a very short rootstock and others have extensively creeping rhizomes (Richards & Clapham, 1941d). The rhizomes bear numerous adventitious roots that penetrate down 15 to 23 cm into the soil. Flowers develop after mid-summer and are wind pollinated. Some arise in autumn others in spring and persist for just one year. Most species germinate in spring and are intolerant of shade.

The main problem species are the tuft forming rushes (Lazenby, 1953). The soft, the hard and the compact rush are of the greatest significance on cultivated grassland. Poor drainage is a common factor in rush establishment. Rushes often arise in disturbed areas or where the sward is weak. Rush infestations were a particular problem after large acreages of poor grassland were ploughed out for cropping during the 2nd World War (Moore, 1949). A survey of the West Riding of Yorkshire in 1946 showed over 10,000 acres were badly infested in that county alone. A similar problem on a smaller scale had followed the 1st World War. However, in most situations rushes form a valuable part of the natural flora and do not need to be controlled. Many species provide cover for wildlife especially wading birds (Wolton, 2004).

The soft and compact rushes were originally classified together as *J. communis* but are now considered separate species (Lazenby, 1953). Several genotypes are recognised. The soft rush is probably the main weedy species, it is widespread and forms tussocks that extend by means of a short creeping rhizome from which new shoots and ultimately new plants arise (ADAS, 1972). It is native in marshes, ditches, bogs, wet meadows, damp woods and by water, mostly on acid soils (Stace, 1997; Clapham *et al.*, 1987). Soft rush is abundant throughout the British Isles and is ubiquitous in moist situations and regions of high humidity. It can become established on a range of soils but is most frequent on base deficient soils and on thin peat (Elliott, 1957). It does not thrive on soils that remain waterlogged throughout the year or ones that dry out in summer. Soft rush is usually found in open situations but will flourish in partial shade. It readily invades undergrazed hill pasture (Richards & Clapham, 1941b). It is not found on arable land (Grime *et al.*, 1988). Undisturbed plants grow into clumps 4 ft tall but mowing or heavy trampling alters this to a more uniform spread of individual shoots. The dense tussock structure and persistent layer of leaf litter deter the establishment of other plants. Soft rush flowers from early June to July in the south and July to August in the north. Seed ripens from July or August onwards but is shed over a long period. In general, plants do not flower until the second year. Flowers are wind or rarely insect-pollinated or are cleistogamous. Seed capsules contain an average of 82 seeds and a plant may produce 700,000 or more seeds (Salisbury, 1961). On average 8 million seeds can be produced on a square yard in one season (Moore, 1949). Laboratory tests have shown that light is required for a high level of germination (Grime & Jarvis, 1976). Red light is effective but blue or green wavelengths are not. Diurnal fluctuations in temperature with an amplitude of 1.5°C promote seed germination in the light (Thompson *et al.*, 1977). Seeds do not germinate until the April following their ripening but can remain dormant for 60 years. In the north of Britain, seedling emergence may not begin until May or June (Richards & Clapham, 1941b). Large numbers of soft rush seeds were present in the soil under coppiced and coniferous woodland (Brown, 1979). Waterlogged conditions are not essential for establishment but a high water table increases seedling emergence (Lazenby, 1953). Seeds require moisture and light for germination, and fields can become infested with seedlings after ploughing. Rush seedling numbers are highest when growing without competition from other species (Lazenby, 1955a; 1955b). The seedlings are extremely susceptible to competition. At first, seedlings are susceptible to drying-out, shading and mechanical damage but once established they become more resistant. Increased soil fertility can promote rush growth but because of the effect on companion species the level of plant competition can also increase. The soft rush rhizomes form a dense horizontal mat 6 to 50 mm below the soil surface (Richards & Clapham, 1941b). Fine freely branched roots extend sideways and upwards from the rhizomes while stout, straight roots penetrate vertically downwards to 25 cm. Shoots begin vigorous growth in March.

The hard rush is the other main weedy species and it occurs on neutral or calcareous clays and alluvial soils often with the compact rush (Richards & Clapham, 1941a). It is rare on acid soils but is tolerant of saline conditions. The tussocks are more open and the rhizome system more extensive than the latter. It is native in marshes, dune slacks, wet meadows or by water on neutral or base rich soils and is common through most of the British Isles (Stace, 1997; Clapham *et al.*, 1987; Gibson, 1997). It is a tuft forming rush with the shoots borne on underground stems (Salisbury, 1961). The hard rush flowers from June to August (ADAS, 1972). The average seed number per

capsule is 67 and there may be 200,000 or more seeds per plant. Hard rush may not set seed every year (Richards & Clapham, 1941a). It forms sterile hybrids with the soft rush but backcrosses to the parents may result in viable seeds. Hard rush seeds require light for germination. The shoots, if grazed, may cause poisoning in sheep and cattle. Cattle that acquire a taste for it may suffer blindness and death (Salisbury, 1961).

The compact rush is a rhizomatous perennial native in marshes, dune slacks, wet meadows or by water on neutral or base rich soils (Stace, 1997; Clapham *et al.*, 1987). It is common through most of the British Isles, although the impression is sometimes given that compact rush is restricted to acid soils. It resembles the soft rush and is often associated with it (Richards & Clapham, 1941c). It is more tolerant of dry conditions but less tolerant of flooding. It is a tuft forming rush with the shoots borne on underground stems (Salisbury, 1961). It occurs in pastures on less heavy soils poor in nutrients. It flowers from early May to July (ADAS, 1972). The capsules ripen from July to September (Richards & Clapham, 1941c). A plant may produce 500,000 seeds (Salisbury, 1961). The seeds germinate in April-May in disturbed ground (Richards & Clapham, 1941c). Flowering stems may fall to the ground allowing seeds to germinate in situ.

The jointed rush is widespread in waterlogged areas in hilly districts (ADAS, 1972). It is a perennial with an extensive rhizome system and forms a sward rather than tussocks but is very variable in habit. Where it has a prostrate habit it may root at the nodes to form clonal patches (Grime *et al.*, 1988). It is frequent on unreclaimed areas (Salisbury, 1961). The jointed rush is also associated with heavily grazed grassland (Gibson, 1997). It is common throughout Britain and is native in damp grassland, heaths, moors, marshes and dune slacks (Stace, 1997; Clapham *et al.*, 1987). It occurs on wet acid soils usually on grazed areas and is absent from dry habitats. The jointed rush flowers from June to September and seed is set from September to October (Grime *et al.*, 1988). Flowers are wind pollinated and jointed rush may hybridise with other species. Even in a grazed site it produces numerous seeds that germinate in spring. Laboratory studies have shown that seed requires high light levels for germination (Grime & Jarvis, 1976). Red light is effective but blue or green wavelengths are not. In a survey of seeds in pasture soils in the Netherlands in 1966, while the jointed rush was uncommon in the sward it was well represented in the soil seedbank (Van Altena & Minderhoud, 1972).

The heath rush is a tough wiry perennial with a rosette of leaves borne at the end of a horizontal rhizome (Welch, 1966). It shows little variation in characters and is sharply distinct from other rush species. It is common only in the North and West of Britain. Heath rush is a sward forming moorland plant with a compact, slow-spreading rhizome (ADAS, 1972). It is common on acid soils throughout Britain (Stace, 1997; Clapham *et al.*, 1987). It is confined to uncultivated ground and is absent from arable land. It is intolerant of shade both as a seedling and when mature, and is absent from woodland and tall vegetation. Heath rush is restricted to wet heaths, upland moors and rough grazing where it is sought out by grazing animals early in the season, so it is a useful food plant rather than a weed. Heath rush is favoured by grazing, without grazing the grasses increase and suppress the poorly competitive rush. It is common where sheep grazing is heavy. The leaves are tough and fibrous but are eaten by cattle, horses and sheep in winter and spring when other

food is scarce. Sheep also eat the developing inflorescences. The growth of new shoots begins in March and increases through April and May. Plants are often 5 years old before they first flower. The flowers are wind pollinated and flowering occurs in late June and July. The seed capsules contain around 50 seeds and ripen from August to October. The capsules open in dry weather and many seeds are dispersed a short distance by the wind. Heath rush has relatively large seeds compared with many other rushes and fewer of them (Cavers, 1983). Some seeds may not be dispersed until the flower stem decays and falls to the ground in spring, resulting in a small patch of seedlings emerging (Welch, 1966). Germination occurs in May and June but a bare area is needed for successful establishment. In closed communities regeneration is mainly by rhizome growth (Grime *et al.*, 1988). Heath rush cannot withstand competition from the fast growing species in base-rich habitats. For this reason it is usually confined to acidic soils or peat but it can grow on a range of soils. It grows on coarse sands and stiff clays but is absent or stunted on dry soils. Heath rush can withstand water logging but not submergence. Burning and treading have little effect. A variety of insects feed on the heath rush and a number of pathogens attack it too.

The blunt-flowered rush and sharp-flowered rush are sometimes a problem in pasture (Wolton, 2004; Gibson, 1997). The blunt-flowered rush is a rhizomatous perennial native in fens, marshes and dune slacks (Stace, 1997; Clapham *et al.*, 1987). It is locally frequent in England and Wales especially in unreclaimed areas (Salisbury, 1961). The horizontal rhizome is far-creeping (Richards & Clapham, 1941e). The blunt-flowered rush has a narrow habitat range and occurs where the groundwater is alkaline. It is characteristic of calcareous peat and has some tolerance of brackish conditions. It flowers in July/August and seed is shed in September/October. In cultivation, seedlings emerge in April/May. The seeds require light for germination. The sharp-flowered rush has a spreading habit and is common in wet pastures (Salisbury, 1961). It is native in bogs, marshes, damp grassland and the margins of rivers and ponds throughout Britain (Stace, 1997). It has a stout, far-creeping rhizome. It flowers from July to September and is the last of the common rushes to flower (Clapham *et al.*, 1987). There are 12 seeds per capsule.

The slender rush is a perennial from North America that was first seen in Britain in 1883 or, according to some, in 1795/6 (Stace, 1997; Richards, 1943). It had been observed in Europe in 1824 (Salisbury, 1961). Within 60 years of introduction it had spread to 50% of the British counties. It occurs on damp barish ground on roadsides, tracks and pathways (Stace, 1997). It is locally frequent throughout Britain. It is a relatively short-lived perennial depending on the habitat (Richards, 1943). Slender rush grows in small tufts with a short upright rootstock but does not form large stands. The erect shoots die down in winter leaving a rosette of green leaves. It has a preference for areas of high rainfall. It does not thrive in closed vegetation but can tolerate shade. It may even flower in dense shade and can flower in its first year. The slender rush flowers from June to September (Clapham *et al.*, 1987). The average number of seeds per plant is 33,000. The average number of seeds per capsule is 268 (Richards, 1943). The seeds swell when wet and burst out of the capsule. The seeds may germinate soon after shedding and may do so while still retained in the capsule.

The most important annual species of rush is the toad rush which is common throughout the UK (Stace, 1997; Clapham *et al.*, 1987). The species now also

includes *J. minutulus* (Grime *et al.*, 1988). It is native in all kinds of damp habitats both natural and artificial. It is found on rutted tracks liable to temporary flooding and in areas of arable land with impeded drainage (Salisbury, 1961). It is often associated with heavily grazed grassland (Gibson, 1997). Toad rush flowers from May to September and fruits from July to October (Grime *et al.*, 1988). Plants may flower within 4 weeks of establishment. The flowers are cleistogamous and there are around 100 seeds per dehiscent capsule. Stevens (1932) gives the average seed production per plant as 5,300 and the 1,000 seed weight as 0.015g. Others give the seed number per plant as 34,000 (Stevens, 1957). Seed dormancy is broken by dry storage (Grime *et al.*, 1988). In a study of seedbanks in some arable soils in the English midlands sampled in 1972-3, toad rush seed was recorded in 34% of the fields sampled in Oxfordshire and 3% of those in Warwickshire but never in large numbers (Roberts & Chancellor, 1986). Toad rush seeds were the most frequent in a seedbank survey of arable soils in Denmark in 1964 (Jensen, 1969). The average number of viable seeds recorded was 26,500 per m². In a survey of seeds in pasture soils in the Netherlands in 1966, while toad rush was uncommon in the sward it was well represented in the soil seedbank (Van Altena & Minderhoud, 1972). In a comparison of the ranking of arable weed species in unsprayed crop edges in the Netherlands in 1956 and 1993, toad rush moved from 22nd to 17th place (Joenje & Kleijn, 1994). It is thought to germinate over a limited period in the year, mainly from April to December with peaks in April and September-November (Chancellor, 1964; 1965). More seedlings are likely to emerge in a soil that has not been cultivated. Laboratory studies have shown that light is required for seed germination (Grime & Jarvis, 1976).

Persistence and Spread

Once established the rushes spread vegetatively and/or by the small seeds that are produced in vast numbers. The seeds are blown or carried elsewhere and germinate from April onward. Rushes are major contributors to the seedbank in a range of grasslands but only low numbers are recorded in the better types of British grassland (Roberts, 1981). The buried seeds can remain viable in soil for 20 years (Wolton, 2004). It is reasonable to assume that land adjacent to a rush infested area, even if it shows no evidence of rushes, will nevertheless carry a high content of rush seed (Moore, 1949). Rush seeds have been recorded in enormous numbers in the soil beneath pastures even though the plants may be poorly represented in the vegetation (Chippindale & Milton, 1934; Champness & Morris, 1948).

In a study of seeds in the seedbank of soils under neglected coppice and conifer woodlands, soft rush was the most abundant seed recorded (Brown, 1979). Seeds of hard rush can remain viable for 7 years in dry storage (Richards & Clapham, 1941a). Those of slender rush remain viable for at least 2 years in dry conditions (Richards, 1943). Seeds of blunt-flowered rush did not germinate after 8 years in the laboratory (Richards & Clapham, 1941e). In a 7-year study of the annual percent decline of seeds in cultivated soil there was no apparent decline in toad rush seeds (Popay *et al.*, 1994). In Belgium, toad rush 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 studies of seedbanks of arable soils in Denmark in 1964 and 1989, toad rush seeds represented approximately 56% of viable seeds in both years (Jensen & Kjellsson, 1992). Seeds of toad rush recovered from excavations and dated at 30 and 300 years were found to

germinate (Ødum, 1974). Viable toad rush seeds were still present in the soil after 100 years under forest (Crocker, 1916).

The production of numerous seeds with high viability and extensive dispersal gives heath rush an advantage in colonising newly available areas (Welch, 1966). Buds in the shoot bases give rise to new shoots on the edge of the rosette and large patches can form which may be over 100 years old.

Soft rush is strongly rhizomatous and may form extensive clonal patches (Grime *et al.*, 1988). In dense communities of soft-rush, vegetative spread is the primary method of reproduction with seedlings developing around the margins (Richards & Clapham, 1941b). The blunt-flowered rush spreads by rapid rhizome extension and new colonies may form when pieces of rhizome are torn off and carried away (Richards & Clapham, 1941e). Its seeds are not mucilaginous and are dispersed by wind and water. Thompson *et al.* (1993) suggest that based on seed characters, soft rush seed should persist for longer than 5 years in soil. It has been reported that seeds may remain viable for 60 years or longer (Lazenby, 1955a). The wind disperses the seeds of soft rush a short distance from the parent, the greatest concentration falling on the leeward side of the plant but few are blown more than 2.5 m (Agnew, 1954). Further spread is by animals, birds, on machinery or in manure and water (Elliott, 1957).

Toad rush seeds have been found in cattle and horse droppings. Where rushes are used as animal bedding the seeds are spread with the resulting farmyard manure. Rush seeds are dispersed by water (Salisbury, 1961). Surface water spreads soft rush seeds down hillsides. Toad rush and soft rush seeds do not float but the seedlings float and may be carried to new sites by flooding (Grime *et al.*, 1988). The seeds of hard rush are dispersed by wind and rain splash, also on the feet of birds and on shoes. Seeds of soft rush, hard rush, jointed rush and North American rush become mucilaginous and sticky when wet and this may aid dispersal in wet conditions. In dry conditions wind dispersal is more likely. The seeds of slender rush also become slimy when wet and adhere to boots and tyres, hence its distribution along trackways.

Management

Control is limited to cutting, cultivating and drainage (Wolton, 2004). Cutting before flowering will prevent further seed shed but there will be many seeds remaining in the soil seedbank (Salisbury, 1961). Cutting may help to stop spread but is unlikely to give good control. Grazing may also help but is unlikely to be effective alone. The hard rush tolerates annual mowing and moderate trampling (Richards & Clapham, 1941a). The compact rush is resistant to trampling (Richards & Clapham, 1941c). The jointed rush can withstand mowing and grazing. The slender rush is very resistant to trampling, cutting and grazing (Richards, 1943). Neither cattle nor sheep have much effect on hard and soft rush in open pasture. Galloway cattle only eat rushes in the first 2 weeks of growth. Sheep will avoid rushes in favour of more palatable grasses (Lake *et al.*, 2001). Wethers (castrated rams) are sometimes used to graze heath rush to encourage palatable grasses in the sward. Sheep confined to small areas at high stocking rates can give improved control of rushes (Popay & Field, 1996). Goats will provide even better control at a minimum stocking rate of 12 goats/ha. In Wales, 20 to 60 goats/ha grazing red fescue/white clover pasture from June to October reduced soft rush tussocks. The greatest reduction was in shorter

pasture, and the suppression was maintained for 3 years. Deer eat small quantities of rushes all through the year (Underhill-Day & Liley, 2006). Topping to 15 cm in early August followed by grazing with hardy breeds of cattle or ponies over 2 years gives good control in uplands (Soil Association, 2002; Backshall *et al.*, 2001). In lowlands, cutting followed by grazing is effective. In lowland areas that flood naturally, topping followed by flooding is effective on wet grassland. Pulling of clumped rushes is another method of control. The application of lime, and keeping rushes cut down or grazed by horses are other measures that may be taken (Morse & Palmer, 1925). The blunt-flowered rush is very tolerant of frequent cutting or burning and of grazing (Richards & Clapham, 1941e).

Control must aim at eradication and preventing re-establishment. Rushes do best on wet soils so improved drainage will help with any control measure. Severe trampling in wet grassland can result in rush infestations developing (Backshall *et al.*, 2001). According to Morse & Palmer, (1925) only good drainage is permanently effective in controlling rushes. However, the presence of rushes is also an indication of an impoverished soil. All rushes are controlled by ploughing or rotary cultivations (ADAS, 1972). A preliminary rotary cultivation may be needed to break up the tussocks before ploughing. On shallow soils ploughing may not be possible anyway. Rushes are prolific seeders, and ploughing or other cultivations may stimulate the emergence of further infestations unless a new sward establishes rapidly. Sowing to a short-term crop followed by further surface cultivations may be best before re-establishing a long-term sward. In an established sward, common rush is considerably reduced by regular annual mowing for hay. Rush seeds require light for germination and seedlings are only likely to emerge in open areas. Rushes will establish rapidly on ground left bare due to poaching etc. Seedlings are sensitive to competition and to moisture deficit but become tougher once established. Detached young shoots of toad rush can re-root after disturbance (Grime *et al.*, 1988).

Mechanical control of soft rush is by ploughing or mowing. Ploughing and reseedling is possible on a drier, level site. Ploughing should be in spring or early summer with good inversion. Plants that are not completely buried are able to re-establish themselves (Lazenby, 1953). Where an uncut field of rushes has been ploughed-in it has been known for the rushes to reappear between the furrow slices. The vegetative tillers grow out into the light and the plants re-establish themselves. Mature plants left fully exposed on the soil surface are susceptible to drying out by the wind and sun. Fourteen days exposure is likely to be fatal.

Mowing should be between July and September, and should be repeated in consecutive years. Cutting to ground level twice a year or once after flowering will reduce plant vigour (Crofts & Jefferson, 1999). If only one cut is possible then cutting in August after flowering is most effective. Where possible the cuttings should be removed. Soft rush is tolerant of annual cutting for animal bedding and is moderately resistant to trampling.

Soft rush is grazed by cattle and rabbits but is not eliminated by this (Richards & Clapham, 1941b). Goats will eat soft rush in grassland, however, high stocking rates are needed to achieve control. Voles destroy grass and kill tussocks of *Juncus* but mosses are not eaten and may increase (Tansley, 1949a).

Rush pastures are important for wildlife (English Nature, 2004). Purple moor-grass and rush pasture is a priority habitat in the UK government's Biodiversity Action Plan. To maintain them, light grazing is needed by traditional breeds of cattle or hardy breeds of pony. Where rushes are being maintained as a habitat for birds such as lapwings, redshank, snipe and curlew, the cutting regime should aim to give a patchwork of grassland and rushes (Arkle, 2007; Crofts & Jefferson, 1999). This is achieved by mowing one third of the area each year between August and November to avoid harming chicks, with a second cut 4 to 8 weeks later. Stocking rates should be kept low to avoid damage to nests during the breeding season and to the sward.

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