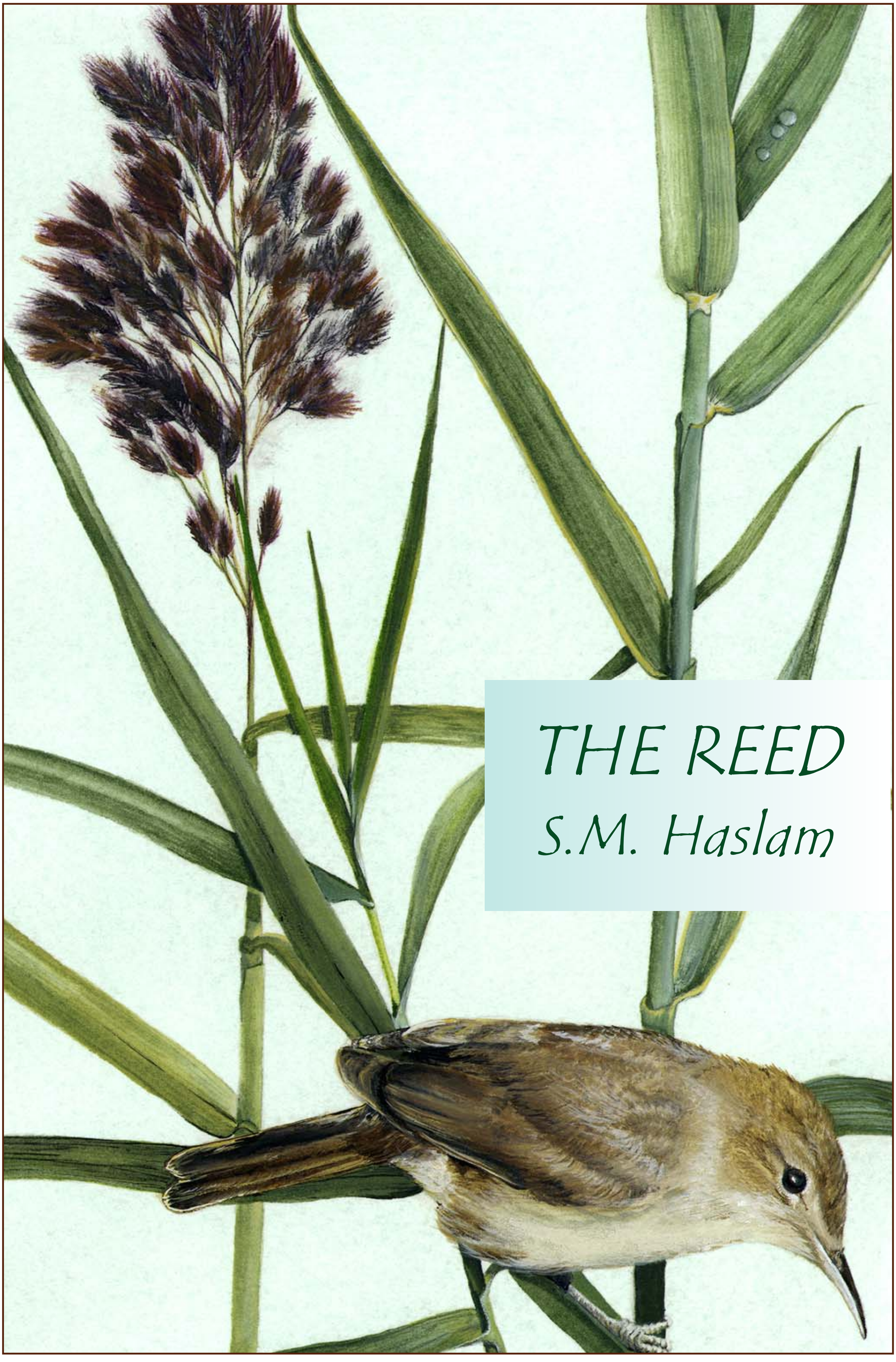


THE REED

S.M. Haslam

First published 1969 by Norfolk Reed Growers Association, Norwich

Reprint with papers by other authors on reedbed management and thatching 1972 by Norfolk Reed Growers Association, Norwich

Updated edition 2009 by the British Reed Growers Association,
Brown & Co., Old Bank of England Court, Queen Street, Norwich,
Norfolk NR2 4TA

Published online at: http://www.brga.org.uk/Publications.html

Cover Picture: August Warbler Tina Bone, AssocSBA.
www.tinabonedtp.co.uk • email: tina@tinabonedtp.co.uk

The Reed

Phragmites australis (Cav.) Trin. ex Steud.

S.M. Haslam, M.A., Sc.D. (Cantab)

Department of Plant Sciences

University of Cambridge CB2 3EA England

Updated edition 2009

British Reed Growers Association

Contents

Please note: numbers in parentheses—(1), (27), etc. within the text— refer to section numbers and their headings in this booklet.

Preface

This booklet was written for the then-Norfolk Reed Growers Association in 1969, incorporating what was known about the behaviour of thatching reed in East Anglia. Since then, the behaviour of reed has not changed, but the background has. For one thing, the Government is no longer proposing to drain The Wash! For another, reed-thatched houses have increased greatly. Most of these used to be straw-thatched. The coming of short-strawed wheat varieties around 1970 meant that straw long enough for thatching became scarce. Many straw-thatched houses were converted to reed, and there were, as to be expected, teething troubles.

Reed thatch must have a steeper pitch (45°–50°), so fillets have to be inserted, and short fine reed (that looking most like wheat straw) holds damp and is not the best choice for, e.g., Devon valleys, where rainfall, humidity and general dampness, are greater than on airy houses in Norfolk. These difficulties were surmounted. British commercial reedbeds had been scattered though concentrated in East Anglia for centuries, supplying buildings near their respective wetlands. (It was not economic to move large loads of reeds far.)

Beds in production had been decreasing over the previous century and a half as demand lessened with the spread of tiles. When demand suddenly increased with the lack of wheat straw, British beds could no longer meet it, and over the next decades much reed has been imported from larger continental reed wetlands, some from as far as Turkey, even China. (In the recession of 2008+, demand and imports decreased, as would be expected.)

This booklet, however, is still East Anglian-based, because the (British) reedbeds are there. The general principles apply elsewhere, but not, e.g., the dates of emergence of the young shoots. This edition has been updated, but remains local. For a wider perspective, see A Book of Reed, Forrest Press, Cardigan, also 2009, by the same author, which contains many more references to the reed literature than are listed here. For British Reed Growers Association members there is also the 1995 Reed Research Report, and annual updates, on-line. (Reports, not publications.)

Acknowledgements

Most grateful thanks are due to the Reed Growers, who so kindly permitted access to their land, and who gave so much useful information. As also to the cutters and thatchers, who gave me the benefit of their experience.

In recent years, Mr R. Jeffries has sampled the reedbeds for the annual monitoring, funded by the Broads Authority. I very much appreciate this.

The Reed, *Phragmites australis* (Cav.) Trin. ex steud.

1. Use of Reeds

The reed, *Phragmites australis*, is harvested for thatching in East Anglia and this booklet describes behaviour and management there. (For other regions and countries and other uses, see the Reference list at the end.)

Reeds, which are the aerial shoots of *Phragmites* are abundant and indeed cosmopolitan in wet places. In Britain production is unequal to the demand from the thatching industry and up to 90 per cent of that used is imported from Europe (The Netherlands, Poland, Hungary, Austria, etc.) and the Middle East (Turkey, etc.).

The second largest use of reed in Britain is to clean polluted water. Constructed wetlands are spreading fast. They are generally as effective as Sewage Treatment Works, but require far more space to do the same purification. They are therefore used for small effluents and pollutions, such as from factories, isolated hamlets, recreation places, motorways and the like.

2. Distribution of Thatching reed in Britain

Reeds are most common in lowland and coastal marshes, but are widespread throughout Britain, being found in small patches as well as covering wide expanses of marsh. Large coastal reedbeds, found at the back of saltmarshes where freshwater dilutes the sea water, are most common round the south and east coasts. Freshwater reedbeds occur on low-lying ground near river beds in alluvial plains or on lake shores. Since reedbeds require a fairly high nutrient status (10), the greatest areas of such beds are in East Anglia where there are large and nutrient-rich wetlands. Reeds are abundant in wetlands near the main rivers (Waveney, Bure, Yare, Little Ouse, etc.), their tributaries and Broads.

In the past, reeds were exploited wherever they grew in quantity. With the spread of cheap alternatives for roofing, fencing, etc., and the increased costs of harvesting, and maintaining small reedbeds, only the larger areas are now exploited: East Anglia (with which this account is concerned), South Wales, and the south coast of England to a limited extent, and very little elsewhere.

3. Reeds for Thatching

Management in East Anglia aims to produce as much reed as possible of a quality suitable for thatching. This means relatively short and long-lasting reeds. Hence management techniques may differ to those on the continent.

Table 1 shows the characters of reeds unsatisfactory for thatching, as assessed by thatchers. The information was provided when reed supplied exceeded demand, so individual thatchers could choose what each preferred. When supply is short, all except the worst reed will be used. Good reeds are therefore hard and straight, uniform in height and width, tapering in bunch, with sparse feather (inflorescences)—and resistant to decay. There should be as little old reed as possible in with the new.

The reed should be suitable physically for easy handling during thatching. It should as well be suitable structurally and physiologically for durability on the roof. Within this framework, reeds can vary greatly, and different reeds are preferred by different thatchers and for different purposes. Some use can be found even for reed of the worst physical quality, provided it is durable. Harvesting was traditionally by hand, the marshmen finding summer employment in, e.g., fishing. Machines are now usually used, their sizes ranging from the alanscythe to the harvester. Harvesting involves cutting and bundling the reed, cleaning weeds and litter from it (most reed is sold 'clean'), and removing the bundles to central points for stacking and storage.

Reed is sold in bundles (bunches). The British Reed Growers Association standard bunch is 61 cm (24 in) in circumference 30 cm (12 in) from the butt (lower end). A fathom is six standard bunches 1.8 m (6 ft) in circumference, 30 cm (12 in) from the butt ends when these are placed together. Commonly, long reed is that over 1.8 m (6 ft) from the butt to where the bundle tapers very sharply near the tip, medium is 1.4–1.8 m (4 ft 6 in to 6 ft) and short reed is below 1.4 m (4 ft 6 in).

Reed beds of high productivity yield *c.* 400 bundles per acre single wale, or 400–500 bundles double wale. Some are cut single wale (annually), some double wale (biennially). Fen sedge (*Cladium mariscus*) is an accessory crop, since, being flexible, it is better than reed for ridges of roofs. Mixed reed, containing some reedmace (*Typha* spp.) and perhaps gladden (*Iris pseudacorus*) is locally cut for thatching. Sheaf, summer-cut reed mixed with other marsh species, is also produced locally (outside Norfolk this may be known by other names, e.g., litter). One bundle per square foot is usually used, giving a thatch 30–40 cm (12–15 in) thick. The cost is *c.* £35–£60 per square (100^2 ft) (2007), the usual cost in Norfolk being *c.* £35–£40 per square (2007) for a straight piece of roof, with gables, patterns, etc., costing more. Although costing more than tiles, a roof thatched by a skilled thatcher with quality reed will last *c.* eighty years.

Table 1. Characters of unsatisfactory reed

Character	See Section:	Comment
break easily when handled	14, 20, 21	
soft, squash easily	20, 21	used for ridge rolls
bottoms squash easily	20, 21	
become soft after thatching	20	
shrinks after thatching (usually soft)	21	
reeds very rough	7, 14	can be used
sheaths fraying from reeds	7, 14	
broken ends jagged and uneven	20, 21	usually only on decayed reed
bottom blackened	21	if due to decay, disliked; if due to growing in shallow water (and so hard), liked
bent or curling	22	used for filling in
bent at knots, 'dog-legged'	22	used for filling in
too much feather (flower and fruit)	26	
too little feather (flower and fruit)	20, 21	as indicating double wale or older reed
feather uneven, throughout upper half of bundle	16	feather preferred in to 12 in (30 cm)
many short reeds in bundle of medium length	9, 16, 11, 15	used for cap ends, near top of hipped end
over 10% large (over 1 cm wide) reeds in bundle	9, 10, 26	used for filling in
too long (over 8 ft, 2.5 m) and coarse		
many very wide and very narrow reeds in one bundle		used for cap ends
bundle tapering very much	11, 14, 15, 16,	
middle of bundle fatter than butt (bottom)		
cut with long stubble, leaving hardest part on reed bed (common in some imported reed from tall reedbeds)		

Table Notes:
Ridge rolls: rolls of reed c. 4 in (10 cm) wide fastened along ridge of roof.
Filling in: laying reed along a valley on a roof, to give a gradual curve.
Cap ends: gable ends, where thatch overlaps the end of the wall.
Hipped ends: the alternative to cap ends, where the roof slopes down to the eaves.

Reeds are used for thatching buildings both old and new in East Anglia where it is traditional, as is reed thatch near smaller reed populations. When grain crops became short-stalked in the 1970s, so thatching straw was no longer easily available, many straw-thatched buildings elsewhere were converted to reed. Reed demand therefore spiralled, exceeding the British supply, leading to imports.

4. Arrangement of reedbeds

Most were originally laid out for manual harvesting, usually with transport by boat, which means dykes able to take boats intersected the beds. Some of the existing beds are easily adapted for machine harvesting, others are not. Dykes still cross the larger reedbeds, basically parallel and at right angles to the river, making each bed roughly rectangular. Many are now obsolete and dried. Functional ditches drain the run-off from the higher ground, and regulated the water supply to the reedbeds. Reedbeds connected to a tidal river show tidal fluctuations, up to, e.g., 1.2 m. Otherwise, those with uncontrolled levels are usually wetter in winter than in summer, and those with sluices are dry in winter, to permit easy harvesting, and wet in early summer (9; also see 2).

5. Ecological status of reedbeds

Reeds form part of the ordinary process during which shallow water changes to dry land. As the water level drops (by an actual lowering of water level or by the build-up of alluvium and plant remains forming peat) submerged aquatic plants are replaced by water lilies (e.g., *Nymphaea alba*) etc., and then by reedswamp, with bulrush (*Schoenoplectus lacustris*) usually present with the reeds at first. As flooding decreases, bushes (e.g., sallow, *Salix cinerea*) invade and form a carr, in which alders (*Alnus glutinosa*) become established, and the marsh ends as a wood on dry land. (There are also other sequences of plants.)

Sallow can grow well in ground with intermittent flooding. So all marsh with intermittent or no flooding, whether bearing reed, or fen sedge (*Cladium mariscus*) or, in drier places meadowsweet-rush (*Filipendula ulmaria–Juncus* spp.) or willowherb–nettle (*Epilobium hirsutum–Urtica dioica*) etc., will revert to carr if left untouched for long enough. The reversion may be very slow if litter accumulates, and may be rapid after clearing (by, e.g., irregular harvesting or grazing Haslam, 1972). So most British commercial reedbeds are dry enough to need continual effort to combat bush invasion. Most natural reed is in water too deep to allow easy harvesting. These others are not 'natural' habitat. They are man-made, but unique and of very high conservation and biodiversity value.

Where reed has been cultivated for many years, the ground is often firm and consolidated, while reedbeds newly developed from the Broads are on softer soil. Many wetlands by Broads have only recently become shallow enough for reedswamp, and this has decreased the open water there.

Phragmites peat develops in swamps with little accretion of silt and clay. It is soft, being composed mainly of plant remains, and may be thick. Clay, deposited as mud from large areas of water (e.g., near the coast), is much firmer, and is mainly inorganic. So old reedbeds on clay are on the hardest ground, and ones on new peat, on the softest. Soft ground will not bear heavy machines. On the European continent the commercial reedbeds are mainly on inorganic soil, and so this harvesting problem does not arise.

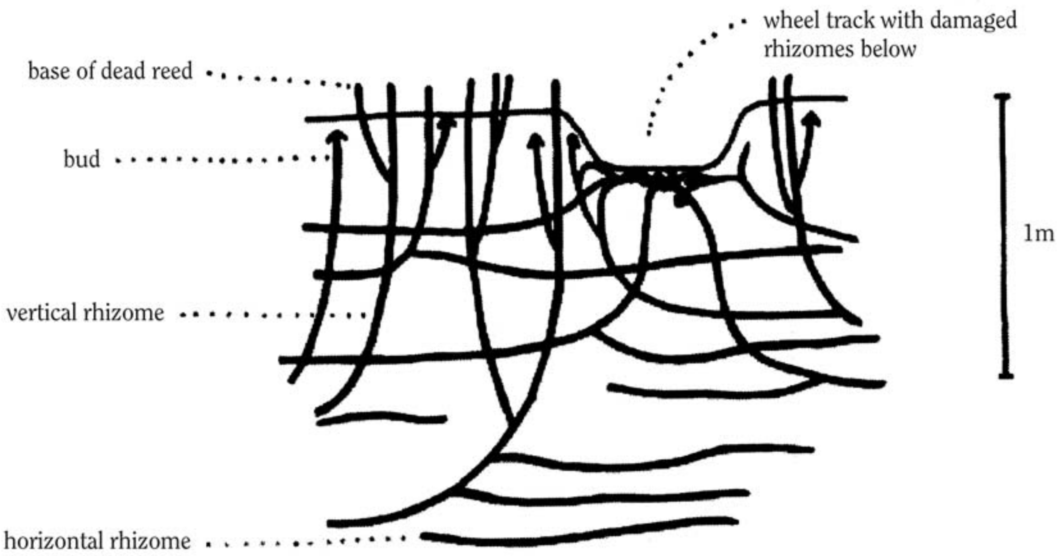
6. Structure of the reed plants

Reed may have more below than above ground parts. The reeds (aerial shoots) are each borne on an upright underground stem, a vertical rhizome (Fig. 1). A main vertical rhizome has, terminally, one of the tallest reeds in the stand, which probably bears a feather (inflorescence). Later this rhizome may branch extensively, bearing *c.* 24–36 reeds in all. These branch reeds are smaller than the terminal one, and the shortest rhizome branches usually have the shortest reeds. Taller reeds are more likely to flower, in any reedbed.

Short, much-branched fibrous roots, often forming a dense rootfelt, grow near the ground surface from the upper parts of the vertical rhizomes; and long, thick, little-branched ones grow from the horizontal rhizomes well below ground level. If the reedbed is flooded for most of the summer, branched roots may also grow from the bottoms of the reeds.

Rhizome leaves are pale, sheathing and membranous, without blades. Above ground, successive leaves become larger and more like the full aerial form with the long blade ('flag'), which appears about one-quarter to one-third up the stem. The green leaf sheaths encircle the stem, and as they do not fall with the blades, are harvested with the stem as part of the reed.

Figure 1. Diagram to show rhizomes of dense reed (and wheel track damage) (simplified)



Horizontal rhizomes grow each year, growing c. (0.5–) 1 (–1.5) m before bending up to become the new vertical rhizomes. These main rhizomes live perhaps 4–6+ years, so rhizomes are always growing and dying, separating the original plants into many different portions and forming the dense network of rhizomes seen in the reedbeds. A large bed can be derived entirely from portions developed from one original seedling, or, more likely, it may come from several. Different originals may respond differently to the same environment.

Once a seedling has become established, reed derived from this may live in that area for hundreds of years. In fact, an age of over one thousand years is cited by Rudescu, *et al.* (1965), for some reeds. Reedbeds can last longer, as is seen in peat sections of ex-lakes and marshes.

7. Variation in reeds

All British reed is *Phragmites australis*. It is obvious, though, that reed can be long or short, fine or coarse, rough or smooth, etc. Some variation is due to inherited (genetic) differences, to differences in *genotype*. A lot is due to differences in environment (soil and water regime, present treatment, past history, etc.). The present reed can be determined by management patterns of at least seventy and probably one hundred+ years ago. These are *environmental* differences. There are also differences due to the rhizome pattern, e.g. larger reeds are usually on younger and longer vertical rhizomes.

Genotypic differences cannot, of course, be altered. Environmental ones can be. Unfortunately, most of the characters reedgrowers are interested in, like length, width, straightness and resistance to fungal decay, can be affected by both types of difference. The only certain way of determining whether bad reed is so because of its inheritance or its surroundings is by testing its DNA and by growing some with good reed in identical conditions for two to four years, and watching whether or not the two become identical.

Plants ultimately derived from one seed form a *clone*, and share the same genotype. It is, however, often impossible to determine different clones in established reedbeds without DNA testing (which gives certainty) or infra-red colour photography and field checking (part certainty, part probability). '*Biotypes*' is used to describe different kinds of reed, however caused (e.g., Bjork 1967, Rudescu *et al.*, 1965). There is variation within and between biotypes. In Norfolk, for instance, the Horsey biotype varies in height and hardness with water regime, and the Cley ones with water regime, weeds and salt. But there are also differences in height, width and texture between and within these. Altering the environment in minor ways produces variations within the biotype. Conversion between biotypes is possible only where the differences are not genotypic, and with a major habitat change, e.g., transplanting, a major change in water regime or chemical status, or (sometimes) burning in spring or summer.

DNA and confirmatory transplant experiments are needed to determine whether an unsatisfactory biotype is genotypically or environmentally poor. If the former, the only treatment is to kill the reed and re-propagate with a better biotype. Since all reed now produced is saleable, this is not economically justifiable. Environmentally unsuitable reed can be given a shock, followed by a different management pattern. This again is costly. The treatments discussed, consequently, are mainly for variation within biotypes: i.e., for increasing the yield of the kind of reed present, not for altering the kind.

New reedbeds are often colonised for free from reed in nearby ditches. If, however, this biotype is poor, it would well repay the extra trouble and expense to propagate instead by transplants from a good and local biotype. (NOT, however, by whatever the local Nursery chooses to provide, which may be no better than the local one and, worse, may be alien!)

8. Propagation in new areas

New East Anglian reedbeds are usually either former reedbeds now overgrown with weeds, or pasture or arable that can be flooded by altering the drainage. Bushes must be removed first, and if large wet-marsh species are abundant they must be decreased, e.g., by flooding or ploughing. If a satisfactory water regime (9) is then established, reeds will normally invade from ditches, etc., and cover the bed in a few years. If invasion is slow, the soil may need attention (10) or vigorous weeds may need eradicating (the measure necessary will depend on the species). The greater the original amount of reed, and the fewer the other plants present, the quicker the advance.

If 'inoculum' reed is absent (or unsatisfactory, 7), it must be propagated. This can be by rhizomes, growing reeds, young plants or seeds (e.g., Bittmann, 1953; Rudescu *et al.*, 1965). The bed should be fairly clear of other plants, and with a good water regime. Old reeds can be dug in late winter, cutting the rhizomes 25–35 cm below soil surface, and planted at intervals over the new bed. Such a transplant can produce 10 m of rhizome and 45 reeds in its second year. Once the transplant is properly established, the ring of dense new reeds on the outside of the clone each year can be 1–50 m wide in good conditions. 'Plugs' of rhizome and reed bases are easier and more likely to succeed.

Propagation by growing reeds should not be attempted without expert demonstration. Seed should be used only after testing for germination (germination rates vary from under 1% to over 80%), and providing an open habitat, with water almost at soil level, nutrient-rich (or medium) soil, and no grazing. Young plants c. 30 cm high, with over twelve shoots and horizontal rhizomes, can tolerate minor variations.

For the conservation of natural heritage, the new reed should not only be appropriate for its use (thatching, water purification), but BE BRITISH OBTAINED FROM AS CLOSE AS POSSIBLE TO THE BED. Reed is not like beetroot. It is a valued native plant, and reedbeds should NOT turn into Dutch or Turkish, etc., ones.

9. Water Regime

This is the primary requirement for a commercial reedbed. Other features of the environment (soil, etc.) are contributory, and increase yield in a good water regime, but cannot compensate for a really unsatisfactory one.

In reedswamps flooded *c.* 1 m deep for much of the year, reed is usually the most vigorous species present and other species give little difficulty. However, harvesting may be restricted to times when drying or (abroad) thick ice permits easy access. On drier ground weeds become more troublesome, and though reeds can grow with a permanently low water level (e.g., over 1 m down), weeds make this impractical. Hence most cultivated reedbeds have the water level fluctuating around ground level for much of the year, to provide both for harvesting and for control of other plants. (Beds flooded all summer may also lead to root development on the lower parts of the reeds.)

Water for reedbeds comes from various sources. Rain and run-off from higher ground fluctuate with the weather. Broads, rivers and large dykes contain enough water to damp down minor fluctuations, but rivers may exaggerate major ones. Water from these is easily, though expensively, controlled. Controls (sluices, gates) used to be for each reedbed, with frequent checks and alterations by the marshmen. More recently, drainage has been more regional. Now, with so much urbanisation and intensive agriculture, flash floods are increasing, and new control measures are needed to keep water regimes stable. Tidal fluctuations vary in amount, but are regular. Spring water is the least subject to variations in weather.

Provided the supply is adequate, the source is immaterial—but see (10). Springs are usually at the head of streams. Tides affect places connected to lower reaches of rivers or estuaries. Beds near large bodies of water may or may not be connected to these. Run-off reaches some beds directly, and others only through a system of ditches.

Provided the reed bed is flooded for at least several months a year, the benefit appears to be the same whether the flood is in winter (as in many uncontrolled beds) or in early summer (as in many controlled ones). To be effective, the flood should be at least 5 cm deep, and during the rest of the year the higher the water level the less the invasion of unwanted plants.

Reed requires **stable** conditions (25). High yields come from many different water regimes **provided they are regular and repetitive from year to year.** It is much more important to have flood or drought at the same season each year than it is to try to avoid either extreme and fail frequently. The crucial levels are those around soil surface. There is little difference in response to water at 15 cm and 25 cm above ground, or the same levels below it, but much to that at 10 cm below and 10 cm above ground level.

Inadequate evidence suggests that a constantly high water level gives a higher yield than a fluctuating regime, and that a constantly low water level gives the lowest yields. However, reed quality, harvesting considerations and the practicability of controlling the water supply must also be considered.

The desirability of flow depends on the definition of flow! Good reed grows well—and has a competitive advantage in—the most stagnant East Anglian marshes. Even though anaerobic conditions are present, how stagnant is this? These have intersecting dykes at frequent intervals, which provide some aeration and flow. Improving flow in the dykes is one of the management methods to improve a failing reedbed. Sedge (*Cladium mariscus*) beds require more flow than reed ones. So although superficially reedbeds may be stagnant, in fact there is, and needs to be, some flow. Rudescu *et al.* (1965), working with larger areas, recommend water flow.

The water annually consumed by a reedbed is *c.* 1–1.5 m, varying with the latitude and site, biotype and weather (Kiendl, 1953; Rudescu *et al.*, 1965). Since the annual rainfall in Norfolk is *c.* 0.6 m, reedbeds there require an additional *c.* 0.4–0.6 m for loss to the air (evapotranspiration), and then above that, the water needed to keep the ground wet. The two requirements can be kept separate. The loss is mainly in the summer months, the really wet soil can be provided in winter or summer. Reedbeds can occur only where groundwater can accumulate (2) (Haslam 1970c).

10. Soil regime

Reed requires soil for anchorage and (except in some lakes) for nutrients. The former gives little difficulty in East Anglia. The soil there is usually fine-textured, which gives a better yield than a coarse one (5) (Haslam, 1972).

In the soil, some of the nutrients are available to the plant, but most are not; although present, they are chemically bound. The proportion of available nutrients is lower the wetter the soil, the less it is disturbed, and the higher the proportion of organic matter. Clay has the most available nutrients, then silty peat, and finally non-silty peat. Non-silty peat occurs at the head of streams, where the incoming water used to be nutrient deficient (springs, rain and run-off). In extreme places, reeds are sparse, short and, in late summer, yellow. Characteristic other plants include black bogrush (*Schoenus nigricans*), sundew (*Drosera* spp.) and bog-moss (*Sphagnum* spp.). Downstream, silting and nutrient status increase, and the dominant species of wet parts are, in sequence, fen sedge (*Cladium mariscus*), perhaps other sedges (e.g., *Carex paniculata*), reed and finally reed-grass (*Glyceria maxima*). Carr or, if bush invasion was prevented, other dry marsh communities (mostly Tall Herb), occur in drier parts. If the other dominants are depressed, reedbeds can be developed anywhere on the nutrient-rich side of the black bog rush–fen sedge transition; or, if the nutrient status is increased by drying, disturbance or fertilisers, on the nutrient-deficient side also.

Nutrients in the plant may have come from the store in the soil, or from the incoming water. Rain and spring water usually contain little. The amount in run-off increased greatly with the increased agrochemicals applied to farmland. Phosphorus and nitrogen are the two generally most important nutrients for fen vegetation, and the Broads Authorities try to limit the amount entering the rivers and the Broads. Beds may be irrigated with polluted water. These are mostly polluted dykes, and beds adjoining higher ground with no ditch between the two (where the pollution is from agricultural run-off). Reeds often grow longer in such places than in beds more distant from the source. Since reedbeds are such efficient purifiers, ordinary pollution is removed within a few metres. Of course in some places there are taller reeds beside dykes and agropollution entries. It is tempting to think it is the extra nutrients that have led to the extra height. It is possible this is so. But in the few areas examined with infra-red colour photography, these tall bands are seen to be different clones.

In the major waterways, nutrients come from the silt, etc., that has always been washed down from the land (though now more), from fertilisers leached from the fields, and from effluents discharged into the river. These last vary from place to place. Reeds are not ordinarily poisoned by effluents in East Anglia, though many other aquatic plants die in the strongly reducing (stagnant) conditions found in dykes with high organic matter and nitrogen (V. Bye, pers. comm.).

Reed rhizomes can go down to nearly 2 m below ground level, and while roots are concentrated in the upper soil, they extend well below the lowest rhizomes. Nutrients from floodwater can be absorbed by water roots, if such are present, and from deposited silt, by the superficial root mat.

On nutrient-rich fen, fertilisers in 'ordinary' quantities added for six years gave no significant increase in yield, and similarly negative results are reported by Rudescu *et al.* (1965). Since so much of any addition, particularly of phosphorus, will be rendered unavailable to plants in these wet places, only high additions could be expected to show results. Such increases in yield have followed great increases in nutrients (Bjork, 1967; A. Szczepanski, pers. comm.), but British reedbeds are not covered in sewage. Recovery after summer cutting is, however, better if fertilisers are added. (Nutrients are drained from rhizomes for young growing shoots. If a second crop is required, the rhizomes may be deficient and benefit from additions.)

A very favourable response is found from reeds in deficient (i.e., black bog rush) areas. As these are of high conservation value, they should not, however, be exploited for reed. No other actual or potential reedbeds are short of nutrients, and the pollution described above ensures a regular intake, which may be very great.

The pH is usually high, as is expected in high-calcium lowland marshes. Polluted irrigation water is (at Horsey and Ranworth) at least one pH unit higher than water on the beds. Nitrogen is not here associated with general performance. Potassium is apparently in ample supply, and reed may have more in the upper soil than do other plants nearby. Phosphorus, the most important single nutrient determining East Anglian fen vegetation, is higher in more mineral, drier and more disturbed soils. Good reedbeds can, however, occur with very low phosphorus levels.

It would appear that nutrients in good reedbeds are not limiting the growth of the reed (11, 20, 22) (Bjork, 1967; Haslam, 1965, 1972, 1995, 2009; Rudescu *et al.*, 1965).

11. Weeds and bushes

What is a weed? A plant in the wrong place. The 'weeds' of reedbeds are native, welcome, sometimes rare or even threatened species. They are weeds only when bulky enough to be incorporated into bundles for thatching. Small amounts, particularly of short species, are not 'weeds'.

If two plants try to occupy the same space, one is likely to succeed and the other to decline. A natural dense reedbed can kill out most competitors, but a cultivated one is normally drier and so more liable to weed invasion (5), and the cutting removes the permanent covering of litter and dead standing reeds that help to keep weeds out. So reedbeds need continuous care to keep down weeds.

Bushes can invade open (including cut) reedbeds that are at least intermittently unflooded—one dry spring in twenty years can produce dense colonisation, and, once established, bushes (e.g., *Salix cinerea*) can stand prolonged flooding. As bushes grow, the area of uncut and shaded reed beside them increases, the patch is more difficult to cut, allowing further invasion, so the marsh changes all too rapidly from a reedbed with scattered bushes to a carr with scattered open patches of reed.

Many herb weeds, in contrast, can be killed by summer flooding for one or several years. Such species can depress reeds in dry places only—but consequently a single dry summer can lower the reed density and height even in a bed which is clean in normal years. The numerous species in this group include some grasses (e.g., *Calamagrostis canescens*, *Arrhenatherum elatius*) meadowsweet (*Filipendula ulmaria*), willowherb (*Epilobium hirsutum*), and thistles (*Cirsium* spp.).

If the weeds are those characteristic of low-nutrient areas (Table 2), flooding with polluted (nutrient-rich water will aid their replacement by reeds. If the weeds are characteristic of high-nutrient areas, removing pollution from floodwater will aid their replacement. Fen sedge (*Cladium mariscus*) can overlap with reed in fairly low-nutrient places (10). The balance is shifted towards reed by winter cutting, increase of nutrient status, and decrease of water flow. Increase of stagnation also increases reed in the presence of reedmace (*Typha* spp.) and possibly reedgrass (*Glyceria maxima*). Bulrush (*Schoenoplectus lacustris*) is unlikely to be a serious pest in beds dry enough for regular harvesting.

A good deal of the depressant effect of many plants is through their cover of living and dead plant material. It is therefore important to keep reedbeds clean, in order to stop the present, as well as the future action of the weeds. Reeds growing with severe competition may taper very sharply.

If increased clearing, increased flooding, or changing the pollution fail to restrain weeds, control measures should be specifically directed against the particular needs of the weeds involved. There are too many possibilities to deal with here.

Weeds can indicate nutrient status. Table 2 shows some common indicators. fen of the lowest nutrient status will not bear dominant reed unless nutrient status is much increased. Nutrient additions might also increase yield in the next groups (10, 12 , 20) (Haslam, 1965, 1971b, 1972, 2009).

Table 2. Species indicating relative nutrient status in or near East Anglian reedbeds

Relative nutrient status	*English names*	*Latin names*
Very low	bog pimpernel, birch, sundew, cotton grass, purple moor grass, bog myrtle, butterwort, tormentil, black bog rush, bog moss	*Anagallis tenella, Betula* spp.*, Drosera* spp.*, Eriophorum angustifolium, Molinia caerulea, Myrica gale, Pinguicula vulgaris, Potentilla erecta, Schoenus nigricans, Sphagnum* spp.
Low	birch, quaking grass, marsh thistle, sedge, cotton grass, fen bedstraw, petty whin, fragrant orchid, creeping rushes, large birdsfoot-trefoil, water mint, bog bean, purple moor grass, grass-of-parnassus, tormentil, great burnett, black bog rush, devil's-bit scabious, marsh valerian	*Betula* spp.*, Briza media, Cirsium palustre, Cladium mariscus, Eriophorum angustifolium, Galium uliginosum, Genista anglica, Gymnadenia conopsea, Juncus articulatus, J. subnodulosus, Lotus pedunculatus, Mentha aquatica, Menyanthes trifoliata, Molinia caerulea, Myrica gale, Parnassia palustris, Potentilla erecta, Sanguisorba officinalis, Schoenus nigricans, Succisa pratensis, Valeriana dioica*
Medium	purple smallreed, tussock sedges, marsh thistle, sedge, meadowsweet, fen bedstraw, marsh pennywort, gladden, creeping rushes, yellow loosestrife, water mint, purple moor grass, marsh cinquefoil, marsh valerian	*Calamagrostis canescens, Carex elata, C. paniculata, Cirsium palustre, Cladium mariscus, Filipendula ulmaria, Galium uliginosum, Hydrocotyle vulgaris, Iris pseudacorus, Juncus articulatus, J. subnodulosus, Lysimachia vulgaris, Mentha aquatica, Molinia caerulea, Potentilla palustris, Valeriana dioica*
High	purple smallreed, marsh marigold, lesser pond sedge, tussock sedge, field (creeping) thistle, marsh thistle, meadowsweet, marsh bedstraw, reed-grass, gladden, (soft) rush, ragged robin, yellow loosestrife, purple loosestrife, great water dock	*Calamagrostis canescens, Caltha palustris, Carex acutiformis, C. paniculata, Cirsium arvense, C. palustre, Filipendula ulmaria, Galium palustre, Glyceria maxima, Iris pseudacorus, Juncus effusus, Lychnis flos-cuculi, Lysimachia vulgaris, Lythrum salicaria, Rumex hydrolapathum*
Very high	oat-grass, lesser and great pond sedges, field (creeping) thistle, great hairy willowherb, goosegrass, marsh bedstraw, ground ivy, reed-grass, gladden, (soft rush), purple loosestrife, reed-grass, nettle	*Arrhenatherum elatius, Carex acutiformis, C. riparia, Cirsium arvense, Epilobium hirsutum, Galium aparine,Glechoma hederacea, Glyceria maxima, Iris pseudacorus, Juncus effusus, Lythrum salicaria, Phalaris arundinacea, Urtica dioica*

12. Chemical control

In general, this is to be deprecated and may be illegal. Marshes are one of the few remaining refuges for much wildlife. Chemical treatment is also expensive.

Burning in late winter or early spring, followed by flooding (e.g., 15 cm deep), should be as effective in depressing most weeds, as well as being quicker and cheaper. In both, a single treatment will not give permanent protection. Where birdlife or protected areas are concerned, it should be noted that selected parts of reedbed can be left unburnt during a fire (as was done at Woodwalton Fen, Huntingdonshire).

13. Buds—size, development and emergence

The size of a reed is determined by the size (width) of the young colt and the environment during its growth. Buds developed in autumn are usually larger than those developed in spring, and those growing from low on the rhizome than those from near ground surface. A uniform stand of reeds develops from a uniform stand of buds. Any bed has both large and small buds, but the small ones are proportionately smaller if the bed is dry, is short of nutrients, or has many weeds. Large buds tend to emerge before small ones, and so a frost or burn in early spring is likely to kill the large ones, and leave the small ones to emerge later. Since replacements for such damaged buds will also be small, the total effect is to increase the uniformity of the stand (16).

Most colts are slightly narrowed on coming through the ground surface, and are narrowed more—making the reeds shorter—in the presence of some weeds (e.g., *Juncus articulatus, J. subnodulosus*).

Buds for next year's shoots start to develop in mid-summer. By the start of winter about half the normal complement of buds has grown near the soil surface and are dormant there. Buds form more slowly in winter, but there is rapid development around the start of the emergence period (usually just before it starts).

Colts can grow to *c.* 20 cm high (with the stem apex still in the ground surface) in any warm spell during the winter. Such colts may be sparse or dense, and are vulnerable to severe frost. They are often common in the *c.* two weeks before emergence begins.

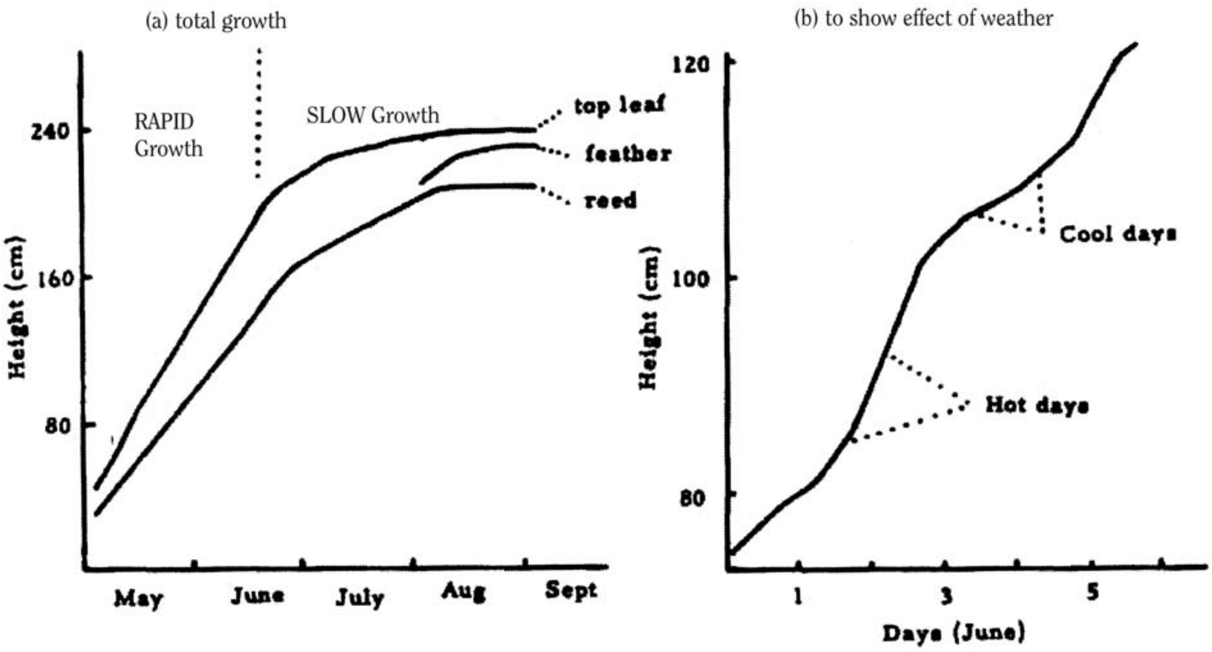
Emergence starts after the internal dormancy control ends (which is probably around late February) and when it is warm enough, which is likely to be one or even two months later, except in frost-free areas and warm years. However, different clones (7) can differ by *c.* three weeks in emergence date, and stress conditions of drought, cold, sea water, etc., can prolong dormancy by several weeks.

Colts emerge during *c.* one month in most cultivated reedbeds without much frost, but it can take longer (up to *c.* four months) with increased frost, increased litter, if burnt after emergence starts, and in some biotypes (7). Only a few colts emerge in the rest of the summer. Shoots killed during the emergence period (by frost, or reedbug (17), or trampling, etc.) are replaceable, but after this period replacements are few (Haslam, 1969b).

14. Shoot development

Reeds grow fast at first, and then slowly (Fig. 2). The food needed for early growth comes mostly from the store in the rhizomes below. Later, the food made at the time suffices both for growth and to replenish the rhizome reserves. The wider the colt, the more food it initially gets from below, and the taller the mature reed—and, often, the faster the growth rate. Short reeds usually cease rapid growth earlier than prospective tall ones, and they grow slowly for longer.

Figure 2. Growth of a tall reed in a dry habitat



Shoots grow faster earlier, and in warmer weather. So a hot spell in May has more effect than one in July. Since, however, late summer temperatures are normally higher than spring ones, a hot summer gives longer reeds than a hot spring, other things being equal (16). Growth is slowed by drought, salt spray, etc.. The day-to-day fluctuations in rate can be considerable, but the overall rate is more steady (Fig. 2).

Management for long reeds should be direct at prolonging the phase of rapid growth, rather than at altering the late phase of slow growth, since no reversion in rapid growth has been seen after the growth has become slow.

The maximum daily growth recorded for the top leaf is 10 cm, more usual rates are *c.* 3 cm in large shoots and *c.* 1–3 cm in small ones. The stem (reed) itself seldom grows more than 5 cm per day, and often only 1–2.5 cm.

The feather (inflorescence) appears *c.* one month before flowering, and there is seldom much rapid growth after this. The feather is late when emergence was late, if the water supply was unusually bad, and in some clones (7). Flowering is usually in late August and early September, and fruits usually ripen in November.

Most reeds are only *c.* 2 mm wide at their tips, but the butts are 2–7 mm or more. So larger reeds taper, typically starting to narrow about half way up. Tapering from near the butt is encouraged by various weeds, shortage of water, of nutrients, and by single wale cutting (which increases density and so decreases the supply of rhizome food available to each reed), and is more in some biotypes (7) than others. The basal leaf sheaths may drop early, and then if higher sheaths are loose or bulky they may swell the width of the reed, and so again make the middle of the reed (and bundle) wider than the butt.

The first leaf blades die and drop in summer, and by September often only the upper half of the reed bears blades. Most of the flag falls by Christmas, and the remainder soon follows. A blade falls after a breaking (absciss) layer forms. The process is hastened but not initiated by frost, the flag falls earlier in a cold autumn, but if immature reed is killed (by frost or cutting) the dead blades remain attached to the reed.

Reed fibres, whose length and number were complete in August, become hard in November and contain their final chemicals in December (Rudescu *et al.*, 1965). This means the reeds, flexible in summer, become non-bendable and fracture easier in winter. Food is moved from the leaves and reeds down into the rhizome. The structural materials are of course left, but the average mineral content decreases by 80–90%.

Unlike the rhizome, the reed (in Britain) lives for only one year. The transition from the long-lived unhardened rhizome to the short-lived reed capable of becoming hardened, is just above soil level. The tip dries first, and death is speeded by cold weather, so that in a mild year much reed will be green at the base at Christmas, and some still green in May, while in a severe one there will be little living tissue in January. Some biotypes die earlier than others (by several months). Butts remain living longer in flooded marshes (where they are protected from frost), and may become dark.

The changes making the reed hard occur before it dies. Consequently, if an immature reedbed is killed by autumn frosts, maturation stops. (In one example, the reeds remained flexible and had lost only 50% of their mineral content.) Provided the reed is in phase with the season it can stand the frost expected at each stage, and low temperatures will hasten hardening, etc., thus permitting early harvesting. But late-emerged reed which is a month or two 'too young' in autumn is liable to be killed, and have its development stopped by frost.

Harvesting is usually *c.* 10–25 cm above ground, in the region somewhat transitional in leaf type between rhizome and stem, where the leaves are close. Since the butt dies last in mild years, in flooded beds and in some biotypes, there is still living tissue in the butt of reed harvested early. Butts are the hardest part of the reed.

15. Population development

As a good reed population develops, the height/number curve passes through the three stages shown in Figure 3. A sub-optimal population only ever reaches the central stage, and a depauperate one never gets beyond the first stage. Optimum and sub-optimum stands are equally satisfactory for harvesting.

Management should be directed at decreasing the proportion of small and of large reeds in the stand, making it more even (Fig. 4, (9), (16)).

Figure 3. Change in growth (height/number) curve through the summer in an optimal stand

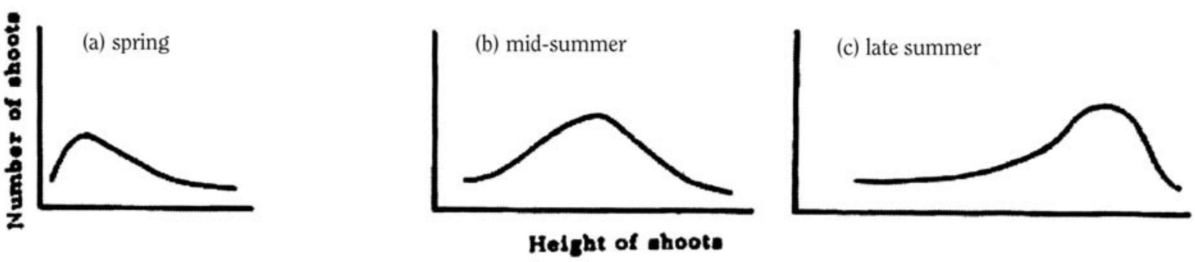
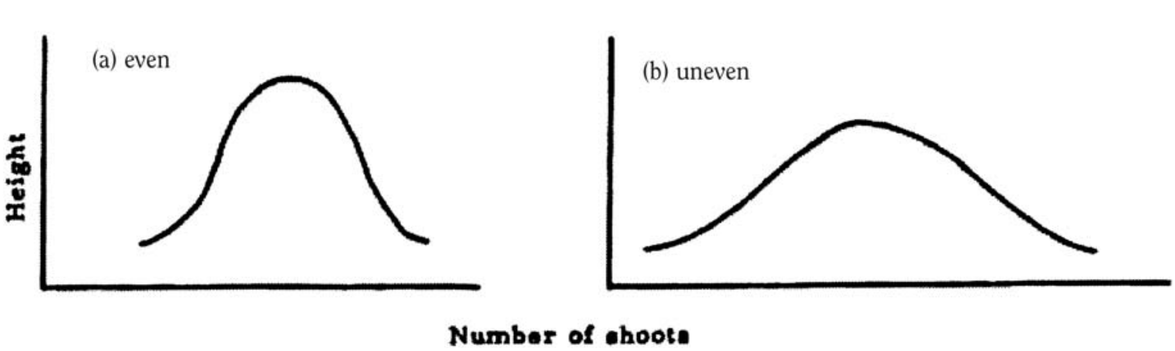


Figure 4. Growth curves of even and uneven reed stands of the same modal height



If the final crop emerges late (due to e.g., frost damage, undue drought, sea water), it may be frost-killed while immature in autumn (14), and the reeds be of poor quality or even unusable. Shoots emerging in May do mature, those of August do not. Usually those of early June will mature, and those of late July will not, depending on the summer temperatures and the date of the first severe frosts.

Late-emerging reeds include those resulting from delayed emergence, replacements for damaged shoots, wide shoots arising late locally, and the usual few small reeds.

The smallest shoots may die in late summer from competition between the reeds themselves. Since those unhardened shoots fall early, this makes the stand more even. In Norfolk, *c.* 1–20% (commonly 5–10%) of the reeds die, so, the loss being higher in uneven stands where little light reaches short reeds and in some very dense beds. The yield can thus be seriously decreased. Only the first possible cause (uneven stand) can be altered easily (16).

All reeds potentially flower, but some are hindered by bad conditions or by being too short compared with the other reeds present. Some shoots are always too small to flower, some tall ones always do so, and those in between are controlled by the environment. More feathers are borne in good weather (normal annual variations *c.* 10%), in local favourable conditions (e.g., 85% by a ditch, 10% far from it), in taller stands, and in uniform stands (small shoots flower more readily if they are not much shorter than large ones). Up to *c.* 90% of reeds in a bed can flower, but *c.* 20–40% is commonly found. Many populations have small feathers on rather short shoots, which appear only if conditions in early autumn are good (Haslam, 1970a, b).

16. Frost, burning, and other effects of temperature

Standing reeds and the litter beneath them insulate the soil from extreme temperatures and damp down fluctuations (e.g., the surface minimum may be 6°C higher under litter and the maximum, 11°C lower). Flood insulates in the same way. Density is usually substantially higher in cleared than in covered areas, and this is accentuated in frosted sites (Table 3, minor differences should be ignored).

Table 3. Effect of removing vegetation on reed density

A. Natural litter, and plots completely cleared in spring.(Mainly summarised from Haslam, 1969b, 1972, in which the control data are given.)

Year	Site	Frost	Treatment	No. reeds per m^2	Modal height (cm)
1957	Icklingham	severe	cleared	392	120
			control	132	135
	Cavenham	very severe	cleared	208	85
			control	88	85
1958	Icklingham	mild	cleared	204	110
			control	184	150
	Cavenham	medium	cleared	336	105
			control	164	120
1959	Icklingham	very mild	cleared	181	165
			control	152	180
	Cavenham	mild	cleared	151	70
			control	69	85

Year	Site	Frost	Treatment	No. reeds per m^2	Modal height (cm)
1965	Icklingham	mild	cleared	260	130
			control	113	150
1968	Woodwalton	very mild	cleared	58	
			control	54	
B. Single and double wale					
1968	How Hill	severe	double	148	120
			single	422	60
1968	Catfield	very mild	double	252	140
			single	*188	130
1968	Ranworth	medium	double	196	140
			single	420	130
1968	Cley	very mild	double	70	**
				162	
			single	258	105

Table Notes:
* edge of wheeltrack,perhaps reduced by this.
** varies with reedbug attack.

The increase on clearing is greatest if this is done in spring. Clearing in November has a lesser, and sometimes even a harmful, effect. (Perhaps the rhizomes then adjust to fluctuating temperature before bud development can take place.)

Frost incidence varies with the year and the site, generally being less near the coast. Although buds in the soil can be killed in winter, the total effect is probably negligible. In spring, damage can be serious, and can occur inland until mid-June. Late killing frosts mean late replacement shoots, with possible harm to the final crop (14). The maximum damage seen is a c. 85% kill repeated several times. Litter provides protection, e.g., a 55% kill in a single wale bed, with only 7% in a double wale one alongside. Floodwater also gives protection.Colts up to c. 30–50 cm high will die if affected by frost, but taller ones (with mature bases) will lose only their immature tips.

Frost damage is usually beneficial, since it usually kills the early large shoots, replacing each by *c.* 1–3 smaller ones, making the resultant crop denser, more even, and shorter. The density can be increased up to 400%. Harm occurs when the damage is late and the crop immature in autumn, and also when the weather is particularly unfavourable and the crop is shortened from both causes, and becomes unacceptably short (e.g., 60 cm high). Such harm is rare.

Severe frosts in autumn can temporarily bend unhardened reed.

Growth rate and final height increase with temperature, and hot summers can have reed 0.5–1 m longer than cool ones (14, Fig. 3), (Spence, 1964).

Burning removes litter and weeds, exposes the bed to temperature fluctuations and frost (see above), and supplies nutrients from the ash.

Burns may be light (some charred plants left standing, nothing affected below *c.* 10 cm, or severe (plant parts 1–2 cm above ground scorched), or very severe (soil surface severely scorched). The last is unacceptable since emergence may be up to two months late, with the crop consequently maturing late (14). Beds are usually burnt between December and early April, after harvesting, and when the weather is suitable and manpower available.

If the fire does not touch reed buds (because the burn is high, the reedbed flooded, or the buds are below ground), the effect is on and through the standing reed or stubble. Internal dormancy is broken, and the previously formed colts emerge in 2–4 weeks if the weather is warm enough.

An early burn usually gives an earlier emergence (since internally the buds are ready to respond to the warmer weather) and does give a more rapid one. One burnt area had six times the density of colts to the unburnt part alongside in May, but in July the latter had increased its density and was only 20% less than the burnt part (explicable solely by the removal of litter). Massive early emergence, and the removal of litter, give reed an advantage over most weeds, and so burning is beneficial for this.

If buds are scorched they will probably die, but the rhizome has been heated and may develop many (e.g., five) replacements at around ground level. So the density increases (up to 600%), the stand becomes even (since so many buds are of the same size), and shorter (since the new buds are small).

The height is lowered usually by 10–20%, but occasionally by 50%. The total yield is much increased (Rudescu *et al.*, 1965, report a 9–90% increase). The effect can, rarely, be unacceptably great, e.g., reducing modal height from 1.8 m to 0.9 m, and modal diameter from 4–5 mm to 2 mm.

Buds can be scorched in unflooded beds with severe burns and buds above the soil. The distribution of such buds before emergence is often patchy, and so the effect also is patchy. If the burn is late, i.e., during emergence, then the crop will arise late, since replacement shoots take 2–4 weeks to come up. Since the weeds are harmed also, this need not be unfavourable to the reed.

Spring burning is the recommended treatment for uneven reed, and, frequently, for sparse reed. The effects may last, but in other reedbeds the effects of burning disappear quite quickly.

Cultivated reeds often have unusually narrow stems and leaf blades. The effect may continue for many years (3–70 years, certainly; 100+ years ?) after management ceases. It is one way of producing new biotypes (Haslam, 1969b, 1970a, b, 1972).

17. Reedbug

Various caterpillars (including *Archanara* spp.) can damage young parts of reed. The attack, in late May and early June, is usually later than frost. Normally only a few shoots are affected, but locally over 80% can be killed. The symptoms (discolouration and wilting of the tips) resemble frosting, but shoots are affected irregularly, not simultaneously. Short shoots are killed, taller ones lose their immature tips only, and basal infection of nearly full-grown shoots does no harm. Since infection is relatively late, many shoots are likely to be affected in the second way. If the attack is dense, it is more serious than frost since replacement shoots will emerge very late and so mature late (14), and where reed bases are left, laterals grow from the stumps. These are very narrow and short, and the final crop, of wide stumps and narrow laterals, is unacceptably short (perhaps half the height of unaffected reed nearby) and too variable in width.

Serious attack is confined to double wale or older beds, where eggs and larvae are on the litter or lower stems. Single wale cutting eliminates the trouble (Haslam, 1970b).

18. Other pests and diseases

Reedbug is the most important pest of reed in East Anglia (17), but several other indigenous animals and fungi are troublesome elsewhere (e.g., Poland, Durska, 1970), and so are potentially of economic importance in Britain.

Lipara lucens, which forms the large galls of reed, seriously weakens infected shoots, and if infection is widespread, the crop is useless. The eggs are usually laid on the taller growing reeds, when 6–10 internodes have developed. Inflorescences are prevented from developing. *L. lucens* is most common in wet marshes on peat, often with alder and birch.

Lipara rufitarsis, which forms the smaller and softer galls, occurs in the same way in the same habitats. But the damage to the infected shoots is less (the loss of height is not above 35% and the loss of strength not above 60%), and as the density of infected shoots is low, a useful crop can be harvested.

Smut (*Ustilago grandis*) infects young colts or shoots, although it is not obvious until July, when sori (*spore clusters*) appear on the under side of the leaf blades, the internodes become swollen, and many very short internodes develop. No inflorescences appear. Flexibility is low, and resistance to breaking is down to half (although the upper stems thicken and harden). Usually only a few shoots are affected, but dense infection renders the crop useless. The amount of infection does not depend on water level, but attack is commonest in tall (over 2 m) and fairly dense or dense (over 70 shoots per square m) reed.

The fungus *Deightoniella arundinacea* (*Napicladium arundinaceum*) produces a dark grey coating of spores on leaf blades and sheaths in June. The stem remains flexible but the loss of strength is up to 86%. The stem does not thicken, the upper internodes are short, and if the inflorescence appears, it is small and does not bear ripe fruits. *Deightoniella* and *Lipara lucens* weaken the stem most, but *Deightoniella* is less likely to attack enough shoots to seriously damage the crop (Durska, 1970).

Other fungi and animals attack British reed, including *Claviceps* spp. (Haslam, 1972), but appreciable damage to the reed crop has not been reported.

Obviously, infected reed may be imported, and handled by thatchers, etc. So far, only a rash on the hands has been reported. Any bad effects should be reported to the Reed Growers Association, for investigation and warning.

19. Salt

Salt (sodium chloride) is the principal solute of sea water, and, in high concentration, is lethal in reed (e.g., Ranwell *et al.*, 1969; Haslam, 1972). There are various effects:

(a) In permanently very slightly salty water, reeds are frequently harder, and, if the stubble is underwater, also shorter than normal.

(b) In some sparse stands in saltmarshes, reed is very hard and short.

(c) In other, wetter ones, particularly in dykes, the reeds are almost unaffected until they reach the lethal limit.

(d) When sea water floods an inland marsh the resultant crop is late-emerging, unacceptably late-maturing, sparse, short—and useless (Buxton, 1938 *et seq.*; and at Covehythe after 1967). It may take several years to drain out the salt, and be longer before the crop is again accepted as satisfactory.

Until further evidence is available, salt should not be added with a view to increasing hardness, and salt should be removed as soon as possible if a bed is flooded from the sea (by flooding and draining).

20. Effects of harvesting on reedbeds

Removal of vegetation exposes a reedbed to greater temperature fluctuations (16) and alters the effect of weeds (11). It also removes nutrients. Leaf blades fall, and their nutrients return to the soil, but the reeds are removed. The total crop (in *c.* September) is *c.* 800–15,000 g dry weight per square m (8,000–15,000 kg per ha) in ordinary good stands. Of this, *c.* 600–1,300 g is stem. Only 10–20% of the mineral content remains in the winter, the average final contents, in g per 100 g dry weight (of some East Anglian reeds), are calcium 0.049, phosphorus 0.017, nitrogen 0.32, potassium 0.087, sodium 0.145, magnesium 0.039, and manganese 0.04. A rough estimate of annual loss (on single wale cutting) in kg per ha, is calcium 2.5–6.5, phosphorus 0.8–3, nitrogen 16–42, potassium 4–15, sodium 7–19, magnesium 2–5 and manganese 0.2–0.5. Most well-managed reedbeds probably have losses nearer the upper than the lower figures.

This is a steady annual drain from the reedbed. To compensate for the loss, greater quantities of fertilisers than the total of nutrients lost would need to be added, as so much of these would be unavailable to plants. However, rivers, dykes, streams, with their nutrients and pollution are giving a constant intake of nutrients, and this appears to compensate, or more than compensate for the loss, in many areas at least. There is, however, a marshman's old tradition that single wale cutting, with its higher yield (16), weakens beds far from the river (i.e. nutrient-poor ones). This could be due to depletion of nutrients. This is now unlikely, as the catchment is awash with agrochemicals. In the 1960s, pilot tests for three years in a nutrient-low area have shown a slight decrease in annual yield in the third year single wale beds (D.S.A. McDougall, pers. comm.). Under a new owner, single wale was again tried. And with the same result! To be sustainable, this bed must be cut double wale.

Green reed (i.e., cut in summer) is cut for sheaf (3), or to reduce the reed. After the emergence period, cut shoots are not (or hardly) replaced, and, with part of the growing season lost, the crop is reduced the following year. Reed is likely to be harmed more than the weeds with it, so summer cutting tends to increase the latter. In unflooded reedbeds the loss in yield after cutting in July was 30–40%, in August 15%, September 3%, and in October *c.* 0.1%. Where the stubble was flooded, the corresponding figures were August 60%, September 40%, October 4%, and November nil (Rudescu, *et al.*, 1965, in reedbeds where the winter water level is lower than the summer one).

The oxygen supply in wet soils is only that provided by roots etc. coming down from the air. Very little oxygen is apparently needed during the winter in fairly dry beds (where it can penetrate down), but lack of aeration in early autumn decreases bud formation. Pilot tests for three years have shown more rapid early growth in a flooded bed with stubble above water level (*c.* 30 cm, taller in early May) and a small increase in final crop (D.S.A. McDougall, pers. comm.), and smaller plots have also shown decreased yield and density when stubbles have been flooded in late winter and spring. Early single wale harvesting, with flooded stubbles, gives the worst aeration for a reedbed. The length of stubble is immaterial for its effect on unflooded beds, but may be important in beds flooded between harvest and when the new colts have grown above water level.

Some marshmen say long stubbles mean reeds branch above ground. This is a misunderstanding of the correctly-observed fact—only living reeds can branch. Long stubble allows *Lipara* spp. etc., to over-winter and cause more damage the next year, which means branched reeds when reed tips are killed.

Harvesting can start when the reeds are hard and mature, usually in late December or January (14), and can continue until the colts are too large (April?). A coarse reed not exposed to frost may be benefited by spinning off the colts in late April, this 'simulated' frost giving a denser and shorter stand (16).

Disturbing the soil damages the upper rhizomes (Fig. 1) and yield can be cut by 20–80% in the affected area (Rudescu *et al.*, 1965). Heavy vehicles do more harm than trampling, and the damage is worse the softer the soil (5). disturbance can also open the bed to weed invasion (e.g., by *Juncus effusus*) (Haslam, 1968, 1972).

21. Decay of reed

Reeds are decayed chiefly by fungi and other small organisms, also by (particularly) sunlight. These breakdown organisms only attack dead reed, and since many infect from the ground, this is not until the butt (the longest-living part) is dead (1), (14). East Anglian reeds typically stand until their third winter (unless affected by harvesting, wind, waves, etc.), becoming softer and paler in colour. Feathers are usually lost in the second summer, as tips of non-bendable old reeds tend to break in the wind when with flexible green ones. The reeds then fall, leaving a short stump above the living rhizome, and the fallen reeds decompose in the damp and infective habitat just above the ground.

Thatching reed is harvested in its first or second winter. That from the latter will be softer and more decayed, hence in general single wale (young) reed will be harder than double wale (part young, part older) reed. Very hard reed (as found in some areas with slightly saline water) may be suitable for thatching even in its third year.

Bundles are stacked to dry, and with proper treatment reach a constant level of dryness in c. 5 months (Fig. 5) Most decaying organisms require damp, and so decay is least the quicker the drying proceeds. In properly treated reed there is a loss, in stack, of hard components (e.g., 4–7% of lignin, 2–3% of ash in cellulose in eight months) and an increase of softer ones (e.g., 1–3% of cellulose) (Rudescu *et al.*, 1965). In bad conditions the loss would be greater. Rudescu *et al.* (1965), recommended stacks built on beams (30 cm high), well separated (by 1.5 m), to avoid contact between reeds and the damp soil, and to allow air to circulate.

Soft tissues decay faster than hard ones. High temperatures speed decay, and the temperatures in stack are high on warm days (Fig. 6). Living (unmatured) reed stacked in warm weather and damp conditions decays fastest, dead reed dried quickly decays least.

Figure 5. Drying of bundled reed in stack (modified from Rudescu et al. 1965)

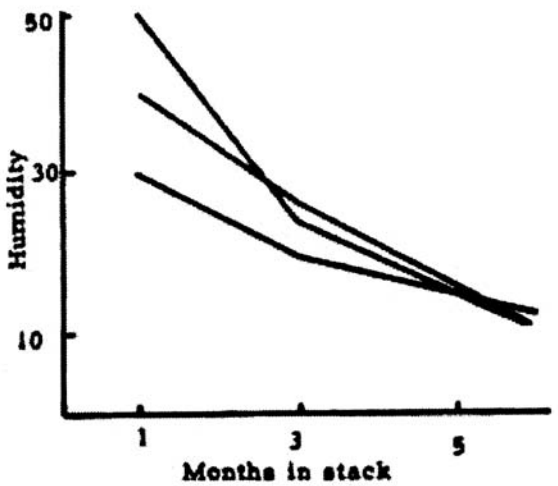
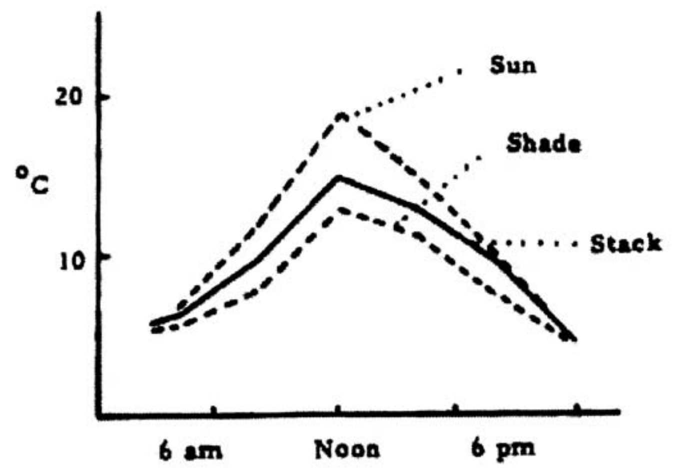


Figure 6. Daily fluctuation of temperature in stack (April) (redrawn from Rudescu et al. 1965)



The most virulent decaying fungus studied (*Coniophora cerebella, C. puteana*) gave a loss of up to 40% in weight and bulk of reed in four months, and up to 70% in weight after six months (Wazny & Wytwer, 1963). Losses anything approaching this are rare. Should they occur, the reed should be destroyed, the area disinfected, and the new stacks sited elsewhere.

As cut reed dries, it shrinks in width. This will be serious only if the reed is cut green (when the shrinkage is greatest) or if it is used for thatching before the shrinkage is complete, when the thatch will become loose, however firmly it was tied originally. Stiffness, tensile and compressive strength of various woods increase during drying (e.g., Jane, 1962). Many biotypes change in strength; some getting stronger, some weaker.

Reed in thatch are dried, hardened, and separated from soil-borne fungal infection. Hence decay is slow, good thatch can last for *c.* 80 years and its final breakdown be due to breakage by birds, etc., as well as to decay. A contrast to the rapid breakdown in the bed! The outer few cm of thatch is exposed to the wearing effects of wind and rain (rain penetrates a few cm only) and to infection by air-borne fungi. So this outer layer determines the durability of the thatch. It is composed of the butt ends of the reeds.

A long-lasting thatch requires good quality reed, properly managed storage and a skilled thatcher.

22. Hardness of reed (and of its butt)

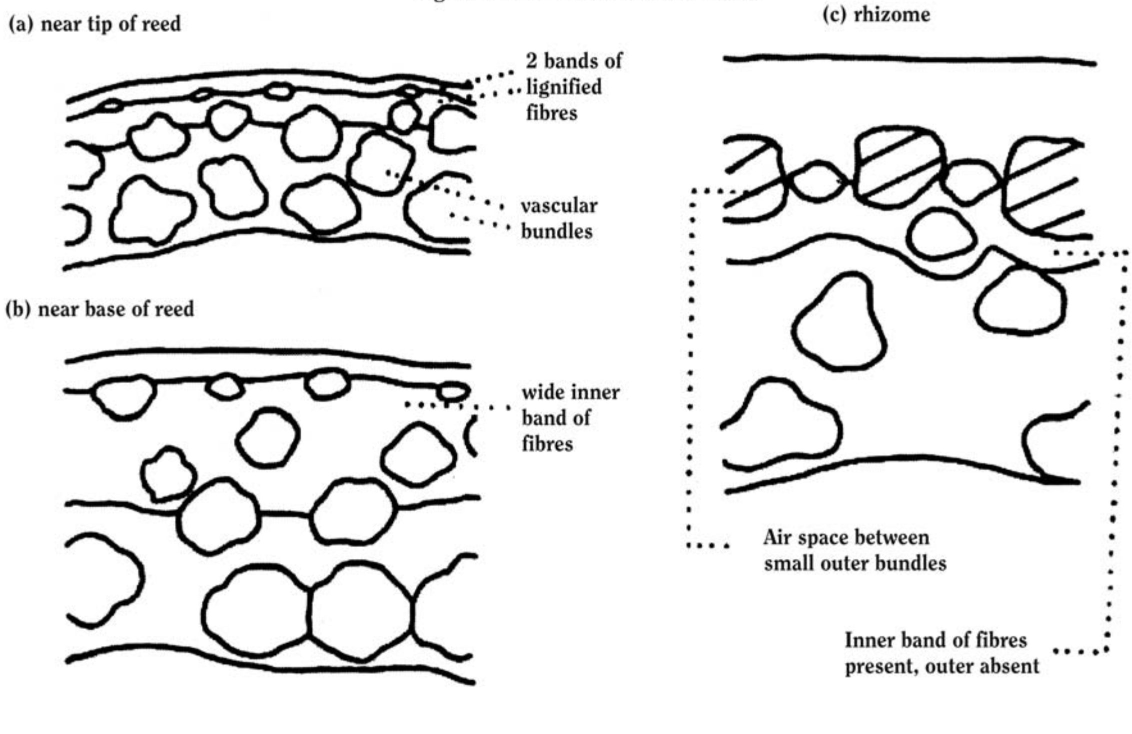
Reed should not break easily, should be hard (and resistant to fungal decay) to be easy to handle and be durable. Only the butt is exposed on new thatch, and so this is then the most important part.

A reed is solid where leaves are attached (the nodes) and hollow between them (the internodes). The bottom, having leaves close together, has a more solid centre than the middle of the reed. Woody (sclerified, lignified) tissue is in bands of fibres parallel to the outside, and woody elements in the vascular bundles (the parts used for transport of substances) (Fig. 7). Since the stem is thicker at the butt than at the tip, the amount (not necessarily the proportion) of woody tissues increases down the stem. If sclerification is inadequate, the reed is soft. On a single, i.e. within one biotype (1), (7), good quality is associated with increased sclerification, but this does not hold between biotypes: a highly sclerified biotype need not be of good quality, and *vice versa*. Within one biotype, the wider reeds are more resistant to breaking than the narrower ones.

The thickness of the tissues compared with the width of the reed is occasionally important, exceptionally weak reed having thin tissues, but ordinarily, relative tissue width has little effect on quality.

The rhizome is soft, though it has one band of fibres. It also has air tubes in a ring near the outside (Fig. 7c). These air spaces decrease in the bottom of the reed, disappearing between *c.* 5 and 25 cm above ground in different biotypes (between the basal region of contracted internodes and the *c.* third uncontracted one). So some reed is cut with air spaces in the butt, and some is not. The former is more porous.

Figure 7. Transverse sections of stem



Biotypes vary in strength, and this is considered more fully in Haslam, 1995–2008; British Reed Growers Association, 2009. Continuous wet weather during maturation prevents the reed hardening properly, as in 1968. This is aggravated if a reedbed normally dry in autumn is flooded during maturation. Such short-term alterations in water regime are often harmful (1), (9), (25). Biotypes also vary in speed of death in winter, with consequent effects on strength.

Chemical analyses of dead reed showed little variation, and no association of content with quality (except the expected result that reed immature when frosted contained more minerals, since the movement of food from shoot to rhizome was incomplete). In one instance, a reedbed with high pollution had higher nutrients (15% higher per g of reed) as well as longer reed than nearby less-polluted beds, but the reverse also occurs.

The butt of the reed will be wetter and more subject to soil infection than the rest. It is also often the hardest part, and, in the work so far reported, is the part most resistant to decay. The butts and parts near the nodes were more resistant than the middle and tip of the reeds and the internodes, in the tests of Wazny & Wytwer (1963).

In wet reedbeds the butt may turn dark or black. On young reed this is a sign of a good water regime and the reed is likely to be hard. If it occurs only on old reed, however, it indicates a rapidly-decaying biotype, with fungal attack well advanced in the second year. This is a sign of poor quality reed. The colouration can be avoided by drying the bed in late summer and autumn, or be removed by cutting the butt end off the bundle.

The hardest and most resistant part of the reed should be on the butt of the final bundles, to stand exposure on the thatch. The work of Wazny & Wytwer (1963) indicates that, in their biotype, reed should be cut with a short stubble for resistance to decay. Reeds dead when cut are likely to be hardest at the base. Long-living biotypes, however, will have living butts if cut early and with a short stubble. Living reed is more liable to shrinkage, and the changes producing hardness are incomplete. The—inadequate—evidence suggests short stubbles are usually preferable, but that in some biotypes and habitats long ones may be better.

23. Straightness of reeds

Dog-legged reed (bent at the nodes) may be curable by single wale cutting, which removes obstructions and increases density and therefore tapering, and a lowering of the water level, or spring burning may also be desirable. If, however, it is a character of the clone (7) concerned, the only remedy is to kill the reed and re-propagate with a better biotype.

Reed may be bent through being knocked over (trampling, storms, etc.) and bending upright again except at the base. Except in extreme conditions this is avoided in double wale beds or with harder reed. Unhardened reed may bend, normally temporarily, in severe autumn frosts. Wind funnelled in one direction may bend reeds. In some stands late (e.g., July) shoots are bent near the base.

24. Length of reeds

Better environments produce longer reeds if density remains stable. Sharp increases in density are usually accompanied by decreased length. Length is under genotypic as well as phenotypic control (7), so no environment will make a genetically short reed grow tall. Details of the factors involved are discussed in other sections and are summarised in Table 4 below.

Table 4. Fault-finder

Character	***POSSIBLE REMEDIES***	*See section*
(a) Too long. Over 10% large (1 cm wide) reeds in bundle	cut, or spin off, young colts	14, 15, 16, 26
	cut single wale	16
	expose to spring frost and temperature fluctuations	
	burn in spring	16
	lower the water level	9
	decrease nutrients and pollution	10
	cut with long stubble	22
	cut bottom off bundle	22
(b) Too many short and thin reeds in bundle	burn in early spring	increase flow
	correct the water regime	16
	do not expose to spring frost (e.g., flood in	9
	spring)	16, 9
	cut double wale	16
	remove weeds	11
(c) Reeds in bundle very uneven in height and width	burn in spring	16
	cut young colts, then flood to prevent frosting	26, 9, 16, etc.
	raise the water level	9
	remove the weeds	11
	stabilise the management	25
(d) Feather very uneven spread over half of bundle	see (c) and (e)	
(e) Too much feather	burn in spring	16
	decrease pollution	10
	lower the water level	9
	hope for bad weather	
	cut off feather before sale: if with fruits, sell for stuffing?	1
	Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
(f) Very little feather	(objected to only as one possible indicator of double wale or older reed)	21
(g) Bundle tapering too much	(i) too many short and thin reeds, see (b) above	
	(ii) each reed tapering too much	
	remove weeds	16
	raise the water level	9
	improve the nutrient status	10
(h) Middle of bundle wider than butt	cut single wale and spring-burn for several years	16
	Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
	lower water level	9
(i) Too short	improve water regime	9
	improve nutrient status	10
	do not burn in spring	16
	do not expose to spring frost	16
	cut double wale	16,26
	stabilise management	25
	remove pollution	10
	remove weeds	11
	remove grazing animals	
	if sea-flooding in past, drain out salt	19
	if liable to flood with brackish water, cut above likely maximum level	19

(j) Too sparse	improve water regime	9
	improve nutrient status	10
	burn in spring	16
	cut single wale	16
	cut in March, not December	26, 16
	expose to frost and temperature fluctuations	16
	stabilise the management	26
	remove weeds and litter	11
	remove pollution by poison	10
	if sea-flooding in past, drain out salt	19
	remove reedbug	17
	remove grazing animals	
(k) Shrinks during storage or on roof	do not cut while still green (time of death varies with frost, local protection from frost, and clone)	22, 14
	Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
(l) Too soft when harvested	if reed immature in early autumn, correct this in subsequent years	14, 15
	if clone dies late, cut in March, not December	14
	Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
	Raise the water level	9
	cut single wale (if clone liable to rapid decay)	21
	if sea-flooding in past, drain out salt	19
	remove pollution	10
	correct the nutrient balance of the soil	10
(m) Becomes soft during storage or soon after thatching	any of the above factors may apply	
	dry bundles rapidly, do not allow to be wet and warm	21
	do not use old reed	21
	if local bad decay, store in another place next year and protect from infection. If on roof, replace affected part and add fungicide near it	21 7, 21, 22
	remember clonal variation in hardness and in susceptibility to decay	
(n) Broken ends jagged	reed decayed. See above	
(o) Bottom of reed too soft, rest satisfactory	do not flood in late summer or autumn	14
	treat for ‘too soft’ as above	
	cut with short stubble to get base of reed (ordinary clone)	22
	cut with long stubble to avoid base of reed (butt unhealthy)	22
(p) Roots on bottom of reed	do not flood in late summer	20, etc.
	cut with longer stubble	
(q) Reedbug infection serious. Reeds ‘branch’ above ground	burn in spring to kill eggs and larvae	20
	cut with short stubble and do not allow litter to accumulate	20
	Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
(r) Bottom blackened	do not flood in late summer	22
	if on single wale, sell to thatcher who prefers this	22
	if on old reed, treat as ‘too soft’	
	cut with long stubble or cut off bottom before selling	

(s) Dog-legged, bent at knots	cut single wale for several years. Remove litter burn in spring	23
	Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
	lower water level	9
(t) curling or bent	erect, or alter position of, wind breaks	23
	if due to severe frost in early winter, will probably straighten later	
	do not knock over, or bend under wheels, when young	23
	if flattened by storm: if rare, ignore; if frequent, treat as ‘too soft’ or cut double wale	23
	if due to colts emerging in June or July, cut with longer stubble	
(u) Reeds very rough to the touch	(i) reed too coarse. Treat for this	
	(ii) Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
(v) Sheaths fraying while dead reed still young	do not cut reed until dead	14
	do not cut reed which was immature in autumn (even if completely dead)	22
	Biotype unsatisfactory. Replacing it is too expensive, changing it (burning, flooding, drying, etc., is of uncertain value except where stated. Usually, therefore, the bed must be put up with.	7
(w) Weeds serious	raise water level	11
	change level of pollution	10, 11
	in late winter or spring, remove weeds and litter by burning (gives selective advantage to reed), or cutting (by hand or machine). Timing to depend on method used	
	decrease flow of water if reedbed wet	9
	if these do not work, take other measures suitable for the weed species concerned	
(x) Bush invasion serious	kill the bushes by burning, cutting, spraying, etc., and remove the dead wood	11, 12
	for prevention: raise the water level, treat as for ‘Weeds serious’	11
(y) Wheeltracks with little or no reed	use heavy vehicles only when water level is low and soil is hard	20

Investigations should precede treatment! Different causes need different remedies, and trying each suggested remedy in turn, without knowing the cause, is not sensible.

25. Stable and stress conditions

The yield of reed depends on the stability and repetitiveness of the environment. Sudden changes, even if not really unfavourable, bring delayed emergence, often a short reed, and a too-early death (13), (14).

In a normal year, reed in the flooded part of a bed will emerge up to two weeks earlier than in unflooded parts, will grow taller, and yellow later in autumn. If, in spring, the wet part should be unflooded, emergence here will be later and the growth less than in the parts always unflooded, and autumn dryness will similarly produce earlier death. It takes several years for a bed to adapt to a new water regime (season of flooding, period of flooding, etc.), and the decreased yields during the interim must be considered when the change is contemplated. Fluctuations around ground level are the most important (9). The effect was seen well in 1968, when a dry spring caused many normally flooded beds to be not or barely flooded. These bore shorter reeds than usual, while other beds were hardly affected (26).

A reedbed is resistant to change. The rhizome is long-lived and contains more food than is needed for emergence and early growth in one year, and the plant is partly self-perpetuating. Hence variations in habitat produce variations in length, density, etc., in any biotype, but transformations between biotypes (7) require a drastic alteration of habitat. Some biotypes can be developed by management techniques (e.g., spring burning), and once formed may be self-perpetuating for long periods, or may throw off the effects of such stimuli fairly quickly. So the biotype may be closely related to either the present, or the past, environment.

Ordinary management techniques alter productivity within biotypes, but do not alter the biotype.

26. Productivity

Productivity of most crops has increased greatly this century, partly due to improved varieties, and partly due to improved management. Reed productivity is limited by the necessity to have small reeds for thatching. And since all the reed now produced is saleable it is not worthwhile to replace biotypes sub-optimal for thatching. Management must avoid increasing bundle length beyond 1.8–2.4 m (22). Most fluctuations in environment are harmful at least in the short term (25), and except in low-nutrient areas short term additions of fertilisers (in order quantities) show no certain increase in yield (10). So the field for changes in management is limited. Increasing water flow may help in the most stagnant beds. Since productivity of different reedbeds differs, though, there is still room for increases.

Management patterns are often traditional. Such techniques were usually developed as the best possible in the existing circumstances. In the last century there have been drastic changes in nutrient status and water regime in many areas, and so the basis for the management patterns may have disappeared. They should be assessed in the light of the environments and biotypes involved now.

In the Danube delta, where large reeds were acceptable, as production was for cellulose, production rose from *c.* 7 mt per ha to *c.* 14 mt per ha in fourteen years, mainly by alterations in the water regime, by burning, and by increased mechanisation (Rudescu *et al.*, 1965).

Costs

Harvesting is done by hand, by small machines (e.g. alanscythe) and by large harvesters. The latter are naturally the quickest, but the effective costs depend on the size and accessibility of the reedbeds concerned (soil type, (5), (20)). Costs are available from the British Reed Growers Association. Data from East Anglia are not yet available for other management procedures. Rudescu et al. (1965), reporting on the removal of litter and weeds from harvested beds find the area cleared, in ha per man per day, is twelve with mechanical clearing, ten with motorised burning, five with ordinary burning, 0.94 by burning with a flamethrower, and 0.15 by manual clearing.

Weather

Maximum yields are in hot summer with adequate ground water (e.g., from very wet weather in winter and spring, or from artificial irrigation). Water is necessary, but rain is not—rain means clouds and cool weather and so a lowering of the growth rate. So an irrigated bed is most productive in weather which is causing slowing of growth by drought in beds receiving most of their water from rain and run-off.

The relative importance of heat and drought varies with the year and the bed. Drought occurred in late spring in 1968, followed by a cool wet late summer. Generally speaking, where a bed normally flooded in late spring was not, or was hardly flooded, the reeds were c. 0.3–0.5 m shorter than in 1967. Where this did not happen, most reed was as long as in 1967, except the tallest ones in some areas, which were shorter (e.g., by 0.3 m) than in the previous year. A small proportionate shortening due to a cold late summer makes more absolute difference to long than to short reed. Cold in mid-summer when the reeds should be growing rapidly, is worse than cold later when even the maximum growth rate is low. A wet spring, giving high water levels, occurred in 1969, followed by a hot mid- and late-summer. Thus in mid-summer, water and temperature were both satisfactory, and the reeds grew well. Flowering and maturation were also good.

Sunny days are important for growth in spring (Rudescu *et al.*, 1965).

Water regime

The water should be between c. +20 cm and c. -20 cm for much of the year,should include a period of flooding, and should be repetitive from year to year. Additional flooding is beneficial if growth is poor, e.g., mid-summer (in beds with weeds or in a drought), but unless it is to be normal treatment, it must be applied too seldom for the bed to adapt to it (9), (25).

Frosting

Exposure to spring frost—most in unflooded and single wale beds—normally increases yield by increasing density, though the height is decreased. Harm is rare, but can come with very late frosts, and if drought also occurs. If beds are exposed to winter as well as to spring frosts, the benefit is less, and density can sometimes be actually decreased (16).

Spinning off young colts

Locally done, to simulate the effect of frost.

Burning

Burning brings reed up early and removes surface vegetation, thus increasing reed and decreasing weeds. If burning, scorches buds, uniformity, density and yield are all increased, but height is decreased (16).

Mulching with rotary grass cutter

An alternative means of removing litter, which is without the side effects of burning.

Single or double wale cutting

The cost and speed of harvesting, and the birdlife, as well as the productivity, must be considered. Productivity is normally higher (16) and quality better (21) in single than in double wale beds. Double wale reed is typically longer in beds liable to frost, and is more liable to reedbug (17). For removal of nutrients see (10), (20), and for aeration (20).

Time of cutting

Early (i.e., December and January) harvesting exposes beds in the non-beneficial winter frosts, and, if the stubble is flooded, decreases rhizome aeration for a long period. Also, in mild autumns or long-lived biotypes the lower part of the reed may be living, not fully hardened, and so liable to decay and shrinkage in the stack. If the reeds die early, early cutting prevents any decay from infection in the reedbeds. Late cutting leads to the reverse of these.

Long or short stubble

Short is perhaps preferable for reed quality (22) and the effect on the bed (except where bad aeration (20) could be harmful), but the evidence is slight. Short is undoubtedly preferable when pests overwinter in stem bases and litter. If cutting level is high, it could be above the butt. As this is the hardest, so least-decaying part, it is important that it is on the cut reed. Reeds can be checked for the length of the hard butt, to ensure cutting is at a safe level.

Weeds

Their troublesomeness depends partly on the habitat and partly on the species involved. Clearing, burning and flooding are the standard measures (11).

Pests and diseases

At present, damage is usually minor. Parts of a bed are sometimes useless after a reedbug attack, but no large-scale damage has been reported (17), (18). Removing litter (by single wale cutting and perhaps flooding or burning) eliminates any significant damage by reedbug.

27. Faultfinder

At present, all (reasonably durable) reed is saleable. Therefore, expensive management changes are not justified.

Table 4 (see pp. 21–23) is a guide to sources of faults in reed. Some faults can be remedied cheaply, others cannot. Most faults can be caused in more than one way, and one or several possible causes may be acting in any instance. In some places, particularly outside East Anglia, causes not listed here may be operative. Study of the reedbed concerned and the relevant sections of this booklet should indicate which items given could be operative and which are irrelevant.

References

Bittman, E. (1953). Das Schilf. *Angew. Pflanzensoz,* 7.

Bjork, S. (1967). Ecological investigations of *Phragmites communis*: studies in theoretic and applied limnology. *Folia Limnol Scand.* **14**.

Buxton, A. (1938). The Norfolk Sea Floods. *Trans. Norf. Norw.* **14:** 349–373.

Buxton, A. (1940). The Norfolk Sea Floods. *Trans. Norf. Norw.* **16:** 150–159.

Buxton, A. (1943). The Norfolk Sea Floods. *Trans. Norf. Norw.* **19:** 410–419.

Durska, B. (1970). Changes in the reed (*Phragmites communis* Trin.), conditions caused by diseases of fungal and animal origin. *Pol. Arch. Hydrobiol.* **17(30):** 373–396.

Haslam, S.M. (1965). Ecological studies in the Breck fen. I. Vegetation in relation to habitat. *J. Ecol.* **53:** 599–619.

Haslam, S.M. (1968). The biology of reed (*Phragmites communis*) in relation to its control. *Proc. 9th. Brit. Weed Control Conf.* 392–397.

Haslam, S.M. (1969a). Stem types of *Phragmites communis* Trin. *Ann. Bot.* **33:** 127–131.

Haslam, S.M. (1969b). The development and emergence of buds in *Phragmites communis* Trin. *Ann. Bot.* **33:** 289–230.

Haslam, S.M. (1969c). The development of shoots in *Phragmites communis* Trin. *Ann. Bot.* **33:** 695–709.

Haslam, S.M. (1970a). Variation of population type in *Phragmites communis* Trin. *Ann. Bot.* **34:** 147–158.

Haslam, S.M. (1970b). The development of the annual population in *Phragmites communis* Trin. *Ann. Bot.* **34:** 867–877.

Haslam, S.M. (1970c). The performance of *Phragmites communis* Trin. in relation to water supply. *Ann. Bot.* **34:** 571–591.

Haslam, S.M. (1971b). Community regulation in *Phragmites communis* Trin. II. Mixed stands. *J. Ecol.* **59:** 75–88.

Haslam, S.M. (1972). *Phragmites communis* Trin. Biol. F1. Brit. Isles. *J. Ecol.* **60.**

Haslam, S.M. (1973a). Some aspects of the life history and autecology of *Phragmites communis* Trin.. *Polskie Archiwum Hydrobiologia*. **20:** 79–100.

Haslam, S.M. (1973b). The management of British wetlands. I. Economic and amenity use. *Journal of Environmental Management*. **1:** 303–20.

Haslam, S.M. (1973c). The management of British wetlands. II. Conservation. *Journal of Environmental Management*. **1:** 345–61.

Haslam, S.M. (1975). The performance of *Phragmites communis* Trin. in relation to temperature. *Annals of Botany*. **39:** 881–8.

Haslam, S.M. (1979). Infra-red colour photography and *Phragmites communis* Trin.. *Polskie Archiwum Hydrobiologia*. **26:** 65–72.

Haslam, S.M. (1989). Early decay of *Phragmites* thatch: an outline of the problem. *Aquatic Botany.* **35:** 129–32.

Haslam, S.M. (1990). *Phragmites* culm strength and thatch breakdown: Some difficulties. Landschaftsentwicklung und Umweltforschung. *Technische Universität Berlin*, **71:** 58–77.

Haslam, S.M. (1994). *Wetland habitat differentiation and sensitivity to chemical pollutants (non open water wetlands*). Her Majesty's Inspectorate of Pollution, London. 145 + 110.

Haslam, S.M. (1995). *A discussion of the strength (durability) of thatching reed* (Phragmites australis) *in relation to habitat*. Reed research report, Department of Plant Sciences, Cambridge. 56 pp.. (Annual updates follow.)

Haslam, S.M., Klötzli, F., Sukopp, H. & Szczepanski, A. (1998). The management of wetlands. In *The production ecology of wetlands.* (eds) Westlake, D.F., Kvet, J. and Szczepanski, A. University Press Cambridge, pp. 405–64.

Haslam, S.M. (2003). *Understanding wetlands: fen, bog and marsh.* Taylor & Francis, London.

Haslam, S.M. (2009). *A Book of Reed* (*Phragmites australis* (Cav.) Trin. ex Steudel, *Phragmites communis* Trin.). Forrest Text, Cardigan.)

Jane, F.W. (1962). *The structure of wood*. London.

Kiendl, J. (1953). Zum wasserhaushalt des *Phragmitetum communis* und des *Glycerietum aquaticae*. *Ber dt. bot Ges*. **66.**

Larson, P.R. (1953). Environmental effects on wood formation. M. H. Zimmerman (ed.),*The formation of wood in forest trees*. Academic Press. pp.. 345–365.

Murayama, N. (1964). The influence of mineral nutrition on the characteristics of plant organs. *The mineral nutrition of the rice plant*. pp.. 147–172. International Rice Research Institute, Baltimore.

Okuda, A. & Takahashi, E. (1964). The role of silicon. *The mineral nutrition of the rice plant*. International Rice Research Institute, Baltimore, pp. 123–146.

Ranwell, D.S., Bird, E.F.C., Hubbard, J.C.E. & Stebbings, R.E. (1964). Total submergence and chlorinity in Poole Harbour. *J. Ecol.* **52:** 627–42.

Rudescu, L., Niculescu, C., & Chivu, P.I. (1965). *Monografia stufului den delta Dunarii,* Roumanian Academy of Sciences, Roumania.

Spence, D.H.N. (1964). The macrophytic vegetation of freshwater lochs, swamps and associated fen. In *The Vegetation of Scotland.* J.H. Burnett (ed.). pp. 306–425, Edinburgh.

Tobler, F. (1943). Stengenbau, festigkeits und verwertungs unterschiede beim Schilfrohr (*Phragmites communis* Trin.). *Angew. Bot.* 165–177.

Wazny, J. & Wytwer, T. (1963). Badania ad odpornoscia Trazciny (*Phragmites communis* Trin.) na dzialanie grzybow niszczacych drewno. *Folia for polon.* **B5.** 171–194.

Westlake, D.F., Kvét, J. & Szczepanski, A. (1998). *The production ecology of wetlands*. University Press, Cambridge.

A full bibliography of the earlier literature is given in Haslam (1972, 1973a) and, for later publications, see Westlake, *et al*. (1998), and Haslam (2009).

TO DISCOVER • TO ASSESS
RIVER FRIEND
TO CONSERVE • TO SAVE

British Reed Growers' Association

Brown & Co., Old Bank of England Court, Queen Street, Norwich, Norfolk NR2 4TA
Tel: 01603 629871 • Fax: 01603 760756