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Leymus arenarius. Characteristics and uses of a dune-building grass

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SUMMARY

Leymus arenarius (L.) Hochst. has its main distribution in northern Europe. It grows predominantly on the coast where it forms sand dunes, but it is also found away from the coast, especially in Iceland. *L. arenarius* belongs to the economically important tribe Triticeae and can form hybrids with members of other genera in the tribe. The controversial taxonomic history of *L. arenarius* is reviewed. A detailed com-parison is presented with *L. mollis* the most closely related species. Plants growing in associations with *L. arenarius* from different countries are described. Successional processes of vegetation on *Leymus* dunes are described and possible explanations for the decline of vigour of *L. arenarius* are discussed. *L. arenarius* has been used extensively to stabilize drifting sands and to halt eroding fronts; future revegetation work in Iceland depends heavily upon its use. Different uses of *L. arenarius* in the past, for instance as substitute for cereals, are described and the potential for future exploitation, particularly through breeding with cereals, are considered.

Key words: hybridization, lymegrass, reclamation, sand dunes, succession, Triticeae.

YFIRLIT

Melgresi. Séreinkenni og hagnýting

Megin útbreiðslusvæði melgresis (*Leymus arenarius* (L.) Hochst.) er Norður-Evrópa en þar vex það meðfram ströndum og myndar oft háa sandhóla. Á Íslandi finnst melgresi einnig fjær ströndinni. Einnig vaxa í Finnlandi fáeinir stofnar af melgresi fjær ströndinni. Melgresi tilheyrir kornfjölskyldunni (Triticeae) og dæmi eru gefin um kynblöndun melgresis við skyldar tegundir. Ágreiningsefni varðandi flokkunarfræði melgresis eru rakin. Aðallega er þar um að ræða aðskilnað vissra tegunda úr ættkvíslinni *Elymus* í nýja ættkvísl *Leymus*. Einnig eru rakin ágreiningsefni varðandi þróunarfræðilegan uppruna melgresis. Nákvæmur samanburður er gerður á melgresi og dúnmel (*Leymus mollis*). Dæmi eru gefin frá ólíkum löndum um þær plöntur sem mynda samfélög með melgresi. Gróðurframvindu er lýst á söndum þar sem melgresi nemur fyrst land. Melgresi þrífst best þar sem er stöðugt sandfok. Ef sandfok stöðvast hins vegar fara oftast aðrar plöntur að vaxa á melhólunum og melgresið fer þá að hrörna; gefnar eru líklegar vistfræðilegar ástæður fyrir hrörnun þess. Melgresi hefur verið notað í stórum stíl til langs tíma til að stöðva sandfok og hefta jarðvegseyðingu á Íslandi. Landgræðsla ríkisins mun í náinni framtíð leggja mikla áherslu á notkun melgresis. Önnur hagnýting af melgresi hefur verið að nota fræ þess í stað innflutts korns. Frekari möguleikar varðandi þessa nýtingu eru athuguð og þá sérstaklega kynblöndun við hveiti, rúg og aðrar skyldar tegundir. Þeir eiginleikar sem gera melgresið að harðgerðri plöntu, t.d. saltþol og kuldaþol, gætu ef til vill nýst við kynblöndun við aðrar nytjategundir.

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INTRODUCTION

Leymus arenarius (L.) Hochst. is a perennial, rhizomatous dune building grass. A full morphological description of the plant can be found in Bond (1952), Bowden (1957, 1964) and Sigurbjörnsson (1963). The natural distribution of *L. arenarius* is confined mainly to coastal areas of northern Europe (Bond, 1952) but it has been introduced to USA and Canada (Bowden, 1964), to Chile (Dollenz, 1977) and to Greenland (Ahokas and Fredskild, 1991). It is confined to frontal fore-dunes in southern Britain (Moore, 1971) but is a main dune-builder in some coastal areas in Scotland (Bond, 1952; Clarke, 1964). Competition with other dune-building grasses such as *Ammophila arenaria* and *Elymus farctus* may restrict its distribution in certain areas in England (Moore, 1971) and rabbit grazing may be a factor affecting its abundance and distribution (Ranwell and Boar, 1986). In Finland, *L. arenarius* is found on the sea-shore as well as on inland sands along lakes and rivers (Suominen, 1970). More recently inland colonies of *L. arenarius* on roadsides in Finland have been associated with the use of de-icing salt (Ahokas, 1992). *L. arenarius* is the only sand-dune grass in Iceland, where it grows both inland and on the coast (Kristinsson, 1986) (Figure 1 and 2). It is used conventionally to stabilize drifting sands and eroding fronts (Runólfsson, 1987; Ritchie and Gimingham, 1989).

This article reviews the characteristics of the species, its uses in the past and its current uses and its potential for use in the future.

COMMON NAMES

Many common names are used for *L. arenarius*: lymegrass, yellow sea lymegrass, sea lymegrass and beach wildrye; melur, melgras and blaðka (Icelandic); marehalm (Danish); strandrag (Swedish); rantavelma (Finish); Gemeine Strandroggen and bleue Helm (German); Elyme des sables (French).

TAXONOMIC AND CYTOLOGICAL BACKGROUND

L. arenarius belongs to the order *Poales*, family Gramineae and tribe Triticeae. Linnaeus (1753) used the name *Elymus foliis mucronato-pungentibus* for *L. arenarius*, but later added *arenarius* to describe its habitat.

Hochstetter (1848) separated the genus *Leymus* from *Elymus* and chose *L. arenarius* as the type species. Considerable confusion in the nomenclature of *Leymus* still ex-

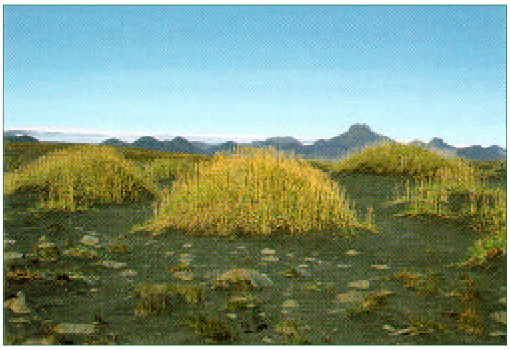

Figure 1. *L. arenarius* can form isolated dunes like this one in the central highlands of Iceland (photo. Sigurður Greipsson).
1. mynd. Melgresi myndar oft staka sandhóla. Myndin er tekin á Haukadalsheiði og Jarlhettur í baksýn (ljósmynd Sigurður Greipsson).

Figure 2. *L. arenarius* can also form a continuous vegetational sward on the coast, like this on the south coast of Iceland (photo. Sigurður Blöndal).
2. mynd. Melgresi myndar oft samfelldan gróðursvörð meðfram ströndum. Myndin er tekin í Þorlákshöfn (ljósmynd Sigurður Blöndal).

ists. North American taxonomists have in the past included the species of *Leymus* in the genus *Elymus* (see Hitchcock, 1951). Their classification is based on morphological continuity between *Leymus* and other perennial Triticeae, suggesting a single evolutionary unit (Barkworth and Atkins, 1984). Species of *Leymus* can be distinguished from those of *Elymus* by their long-anthers and cross-pollination (Dewey, 1983). The separation of *Leymus* and *Elymus* has been adopted by European taxonomists (see Pilger, 1954; Löve and Löve, 1961; Tzvelev, 1976; Melderis *et al.*, 1980; Melderis and McClintock, 1983). Moreover, cytogenetic evidence indicates that species in *Leymus* share the same genomes (i.e. JN) (see Dewey, 1970, 1984; Löve, 1984; Wang and Hsiao, 1984). The N genome is thought to be derived from *Psathyrostachys juncea* (Fisch) Nevski and the J genome from *Elymus farctus* (Savnl. and Rayss) (=*Thinopyrum junceum* (Savnl. and Rayss)) (Wang and Hsiao, 1984). The genomic composition of *L. arenarius* has been proposed to be: $J_1J_1J_2J_2N_1N_1N_2N_2$ (Wang and Hsiao, 1984). Zhang and Dvorák (1991) suggested that the genome of *Leymus* is NN rather than JN (Wang and Hsiao, 1984). Recently, Wang and Jensen (1994) suggested that the genome of *L. arenarius* is NNNNXXXX, where X is an unidentified genome.

RELATED SPECIES

The genus *Leymus* has about 50 species with ploidy levels ranging from 2n=4x=28 to 2n=12x=84 (Dewey, 1983). Eight *Leymus* species are found in Europe (Melderis *et al.*, 1980). The most closely related species to *L. arenarius* is *L. mollis* (Trin.) Pilger (Löve, 1950). The genome of *L. arenarius* has 28 chromosomes homologous with the chromosomes of *L. mollis* (Wang and Hsiao, 1984). The origin of the other 28 chromosomes of *L. arenarius* still remains to be discovered but possibly *L. racemosus* (Lam.) Tzvel. could be the ancestor (H. Ahokas, personal communication). Hence, *L. arenarius* possibly evolved as a result of allopolyploid introgression between *L. mollis* and *L. racemosus*. In fact *L. mollis*, has been treated as a subspecies of *L. arenarius* (St. John, 1915). Morphologically *L. arenarius* and *L. mollis* are similar but they differ cytologically. The main difference between them is that *L. arenarius* is octoploid (2n=8x=56) and *L. mollis* is tetraploid (2n=4x=28) (Sigurbjörnsson, 1960). Also, a reliable difference between the species has emerged from examination of endospermal proteins of high molar mass (i.e. 120–140 kg $mole^{-1}$) (Ahokas, 1992).

Sigurbjörnsson (1960, 1963) examined the morphological differences between *L. arenarius* and *L. mollis*. He concluded that most morphological characters, for example, pubescence of culm collars, spikes, number of nerves per glume, colour of leaves, and texture of glumes overlapped between *L. arenarius* and *L. mollis*. He found only two morphological characters that were useful in differentiating *L. arenarius* from *L. mollis*: pubescence of the culm tops and pubescence of the rachis of *L. mollis*. The latter trait had not been reported before. Unfortunate-ly these findings have not been universally adopted. Barkworth and Atkins (1984) subsequently used the appearance of the glume and the colour of the leaf blades in a key for separating *L. arenarius* from *L. mollis*, even though these characters had already been found to be unreliable elsewhere.

The natural geographical distributions of *L. arenarius* and *L. mollis* are distinct; *L. arenarius* is confined to northern Europe whereas *L. mollis* is confined to north America and Japan (Löve, 1950). Löve (1950) considered that both *L. arenarius* and *L. mollis* grew in Iceland. This statement was later refuted by Sigurbjörnsson (1960) who found only *L. arenarius* in Iceland. Although *L. mollis* has been used by the Soil Conservation Service of Iceland, it has declined or even vanished in those protected areas where it had been sown originally.

HYBRIDS WITH OTHER SPECIES

L. arenarius and *L. mollis* can form a hybrid (2n=6x=42) which exhibits pollen sterility (Wang and Hsiao, 1984; Ahokas and Fredskild, 1991). Sterile hybrids (2n=6x=42) of *L. arenarius* and *Elymus farctus* (=*Agropyrum junceum*) have been reported (Gröntved, 1946). *Secale cereale* and *L. arenarius* form a sterile hybrid (2n=5x=35) (Heneen, 1963; Ahokas, 1970).

Hybrids (2n=35) between *L. arenarius* and barley (*Hordeum vulgare*) have been reported (Tsitsin and Petrova, 1952; Ahokas, 1970, 1973). On the spike of the hybrid between *H. vulgare* and *L. arenarius* there were 6–7 spikelets per node, compared to only 3 on that of *H. vulgare* (Tsitsin and Petrova, 1952).

Hybrids between *L. arenarius* and wheat (*Triticum aestivum*) (Pissarev and Vinogradova, 1944) and *Triticum durum* spp. *Palestinka* are reported (Tsitsin and Petrova, 1952). These hybrids were reported to inherit most characters from *L. arenarius*: they are all perennials that exhibit high vigour and are sterile. Back-crossing with parents did not give any progeny (Tsitsin and Petrova, 1952).

Ahokas (1970) reported an hybrid between *Triticum ovatum* (L.) Raspail (=*Aegilops ovata* L.) (2n=28) and *L. arenarius*. The hybrid (2n=42) resembled *Leymus* but, there was only one spikelet per node.

PLANT ASSOCIATIONS

On the south coast of Iceland *L. arenarius* is found in association with other coastal plants such as *Mertensia maritima*, *Honkenya peploides*, *Silene maritima*, *Festuca rubra*, *Rumex acetosella* and *Potentilla anserina* (Tüxen, 1970). It is also found in association with *Lathyrus japonicus* ssp. *maritimus* (Sigurbjörnsson, 1960). On inland dunes in Iceland it is found typically in association with *Festuca rubra*, *Silene maritima* and *Equisetum arvense* (Tüxen, 1970). When sand deposition ceases, other grass species, such as *Festuca rubra*, *Festuca ovina* and *Poa* spp., invade the dunes and eventually replace *L. arenarius* (Runólfsson, 1978).

Malloch (1989) gave an account of *L. arenarius* communities in Britain, where *L. arenarius* is mainly associated with *Elymus farctus*. Other species that can be found are: *Honkenya peploides*, *Festuca rubra*, *Sonchus arvensis*, *Elymus repens*, *Atriplex glabriuscula*, *Cakile maritima*, *Cirsium arvense*, *Hypochoeris radicata*, *Poa pratensis*, *Taraxacum officinale* agg., and *Epilobium angustifolium* (Moore, 1971; Malloch, 1989).

On the coast of Aberdeenshire in Scotland, *L. arenarius* has been found close to the sea in association with *Cakile maritima* (Trail, 1904). Grasses such as *Ammophila arenaria* (=*Psamma arenaria*), *Festuca ovina* and *Elymus farctus* (=*Agropyrum junceum*) were associates in fixed sand dunes (Trail, 1904). The only dicotyledons associated with *L. arenarius* were *Thalictrum dunense* and *Lotus corniculatus* (Trail, 1904).

In south-west Norway (Karmøy) on mobile dunes, *L. arenarius* is associated with *Ammophila arenaria* and occasionally *Lathyrus japonicus* ssp. *maritimus* (Lundberg, 1987). In Denmark *L. arenarius* is mainly found in exposed habitats on the coast in association with *Atriplex littoralis*, *Cakile maritima*, *Elymus farctus* (=*Elytrigia junceiformis*), *Honkenya peploides*, *Lathyrus japonicus*, *Salsola kali* and *Matricaria maritima* (=*Tripleurospermum maritimum*) (Vestergaard, 1989). In southern Sweden, plants associated with *L. arenarius* on coastal foredunes are mainly *Honkenya peploides* and *Elymus farctus* (Olsson, 1974). In Finland on fore-dunes at Kalajoki on the Bay of Bothnia, the associated vegetation of *L. arenarius* is made up of *Festuca ovina*, *Hieracium umbellatum*, *Rumex acetosella*, *Pleurozium schreberi* and *Achillea millefolium* (Heikkinen and Tikkanen, 1987).

VEGETATIONAL DYNAMICS ON *LEYMUS* DUNES

Sand-dune systems have received much attention because the obvious primary succession that they demonstrate was the subject of early, classical studies (Cowles, 1899; Warming, 1909). Vegetational dynamics are easily demonstrated on *Leymus* dunes (Sveinsson, 1953; Sigurbjörnsson, 1960; Runólfsson, 1978; Greipsson, 1991). *L. arenarius* changes soil conditions and microclimate, which become more suitable for later successional species.

A decline of vigour in *L. arenarius* is commonly observed on sand dunes in Iceland that have become stabilized and colonized by other vascular plant species (Greipsson, 1991). High dunes where *L. arenarius* has lost vigour can begin to erode; this can lead to regression of the whole ecosystem (Sveinsson, 1953). Sand accretion has been found to be an important abiotic factor influencing vigour of sand dune grasses (Marshall, 1965; Hope-Simpson and Jefferies, 1966; Eldred and Maun, 1982; Greipsson, 1991). When sands are stabilized other species invade the dunes (Runólfsson, 1978). Competition with other species is probably not a major factor in the decline of *L. arenarius* on stable dunes. On the other hand, Watkinson *et al.* (1979) considered that competitive interactions for nutrient resources appear to be responsible for the decline of even the most vigorous sand dune plants.

The absence of safe-sites for germination (cf. Harper 1977) could also be a reason for the decline of *L. arenarius* after the invasion of other species. Changes in certain physical phenomena associated with increasing plant cover could cause this. The maximal fluctuations in temperature and soil moisture occur at or near the soil surface in open early successional habitats (Bazzaz, 1979). Plants add litter and dampen temperature oscillations, and uniform temperature inhibits germination of *L. arenarius* (Greipsson and Davy, 1994).

Recognition of possible successional pathways on sand dunes could have some applications, since the struggle of pioneer plants on sand dunes could indicate possible methods for stabilizing drifting sands. In particular, information on sowing time of new species to sustain the succession in a reclamation programme is needed.

USE IN RECLAMATION WORK

L. arenarius has been used to stabilize drifting sands and eroding fronts in Iceland for more than a century (Sigurjónsson, 1958a). *L. arenarius* has also been used to halt erosion of coastal regions in Great Britain (Cole, 1959; Hobbs *et al.*, 1983; Ranwell and Boar, 1986; Ritchie and Gimingham, 1989), in Denmark (Hansen and Vestergaard, 1986) and in Poland (Piotrowska, 1988). Without the use of *L. arenarius*, sand reclamation work in Iceland would probably be impossible (Thorsteinsson, 1973; Runólfsson, 1987). At first the stabilization of blowing sands was very difficult because of a lack of seeds (which had to be collected manually), problems with storing seeds and unsuitability of the varieties of seed available (Sigurbjörnsson, 1960). These problems have now been substantially solved; harvesting is now mechanised, seeds are stored in ventilated containers, and selected types are harvested (Greipsson, 1991). Although *L. arenarius* has been used extensively for a long time, some problems are still encountered in its use. The main problems are associated with germination (Bjarnason, 1982) and seedling establishment in the field. Seeds are usually sown with seed driller. Best results are obtained if plants are fertilized and protected from livestock grazing for several years. Timber and stone windbreaking fences were the first methods used to prevent sand drift and *L. arenarius* was sown on the sheltered side (Sveinsson, 1953; Sigurjónsson, 1958b). *L. arenarius* is also sowed into drifting sands in continuous strips at right angles to the prevailing wind direction. Eroding fronts have been particularly difficult to vegetate, owing to the thickness of the soil mantle and its movement caused by wind and frost-heaving, but *L. arenarius* has proved to be useful in certain situations.

Once *L. arenarius* has stabilized drifting sands, the area is usually sown with *Festuca rubra* and fertilized, to revegetate the area completely. Coastal sand dunes are very common in Iceland and their vegetation is extremely fragile (Greipsson and El-Mayas, 1994). To stabilize coastal sand dunes *L. arenarius* is sown in continuous strips just above high tide levels. Some of those coastal areas have a constant supply of sand from the sea and need long-term protection (Greipsson and El-Mayas, 1994). Flooding during high tide, especially in the winter when storm-surges and ice-thrust add to the force, is responsible for the destruction of coastal dunes and makes reclamation of these areas very difficult. The potential benefits of sand reclamation are enormous (Greipsson, 1993; Greips-son and El-Mayas, 1994). Large districts have been devastated by sandstorms and several farms had to be abandoned during the last century, especially in south and north-east Iceland (Sveinsson, 1953). On the south coast of Iceland, sand stabilization has saved several successful fishing villages from being abandoned (Sveinsson, 1953).

USE FOR HUMAN CONSUMPTION

Seeds of species within the genus *Leymus* have been used in north America, Russia and Iceland as a substitude for cereals for human consumption (Olafsen and Poulsen, 1772; Hólm, 1781, 1782; Scribner, 1900; Tsitsin and Petrova, 1952; Darlington and Wylie, 1955). Hólm (1781, 1782) described methods of harvesting, threshing and milling for the use of the seeds of *L. arenarius* in the south of Iceland. The quality of flour made from seeds of *L. arenarius* is considered to be high (Henderson, 1818; Ingo, 1950). The use of the seeds of *L. arenarius* as food was mainly local on the south coast of Iceland, until 1945 when its use ceased. Many problems were associated with its use but probably the most serious one was the frequent occurence of ergots (*Claviceps purpurea*) on the spike. Ergots, if consumed could cause hallucination or serious illness.

OTHER USES

Straw from *L. arenarius* was used for thatching roofs, insulating the walls of houses and for making small mats (Olafsen and Poulsen, 1772). Roots and rhizomes were used for ropes, saddles and brushes (Hólm, 1781, 1782; Halldórsson, 1783). Hólm (1781, 1782) gave an account of hay making with *L. arenarius*. Hay of *L. arenarius* is considered to be better for beef production than for dairy cows (Halldórsson, 1783). Wild stands of *L. arenarius* are valuable for grazing for sheep, especially in the spring (Kristmundsson, 1958; Sigurjónsson, 1958b). It is however, very vulnerable to grazing. An account of the uses of the related *L. mollis* in north America can be found in Klebesadel (1985).

FUTURE USES

Sand stabilization in Iceland will continue to depend heavily on the use of *L. arenarius* and much work is needed. It will be more practicable if *L. arenarius* can be cultivated in fields for seed production; harvesting seed from wild stands is difficult because of the formation of dunes by *L. arenarius*. A breeding program with *L. arenarius* and other species within the genera *Leymus* could result in hybrids with a wider range of habitat preferences than *L. arenarius*.

A breeding program involving *L. arenarius* and cereals such as wheat (*Triticum aestivum*), rye (*Secale cereale*) and barley (*Hordeum*) is desirable and might result in a useful crop for northern latitudes. Characters such as salt tolerance, large numbers (200 to 300) of seeds per spike and cold tolerance are found in *L. arenarius* (Greipsson, 1991). These traits could increase the use of cereals if incorporated into hybrids, especially in cold temperate areas or where soils are affected by high salinity. Considerable concentrations of the amino acid lysine have been found in the proteins of seeds of lymegrass and this fact makes it interesting for hybridization with cereals (H. Ahokas, personal communication). Also, dough made of low quality wheat could be improved by adding flour of lymegrass since it is cohesive and very viscoelastic (Ingo, 1950).

Breeding between *Leymus* species and wheat (*Triticum aestivum*) has resulted in hybrids that are more resistant to viral infection (Plourde *et al.*, 1989, 1992). Crossing of *Leymus chinensis* (Trin) Tzvel. and *Triticum aestivum* has resulted in hybrid which is resistant to plant diseases (i.e. leaf rust and powdery mildew) and has seeds with a high content of lysine (Yuansheng *et al.*, 1988). Future breeding potential of *L. arenarius* with wheat is being exploited at the Agricultural Research Institute at Reykjavík (Kesara Anamthawat-Jónsson, personal communication).

Ergot (*Claviceps purpurea*) is found on the spikes of *L. arenarius* especially during summers with much rainfall (Davíðsson, 1960). Although ergotted heads are poisonous when consumed, they do have pharmaceutical uses. It is possible that fields of *L. arenarius* could be infected with the ergot and subsequently harvested. Ergot is used to make the drugs ergotamine, ergobasine and lysergic acid derivatives (Strasburger, 1980; Voss, 1991). The two former drugs are used in gynaecology and the latter in the treatment of nervous disorders. Alkaloids in ergot possibly still remain to be discovered (Strasburger, 1980; Voss, 1991).

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