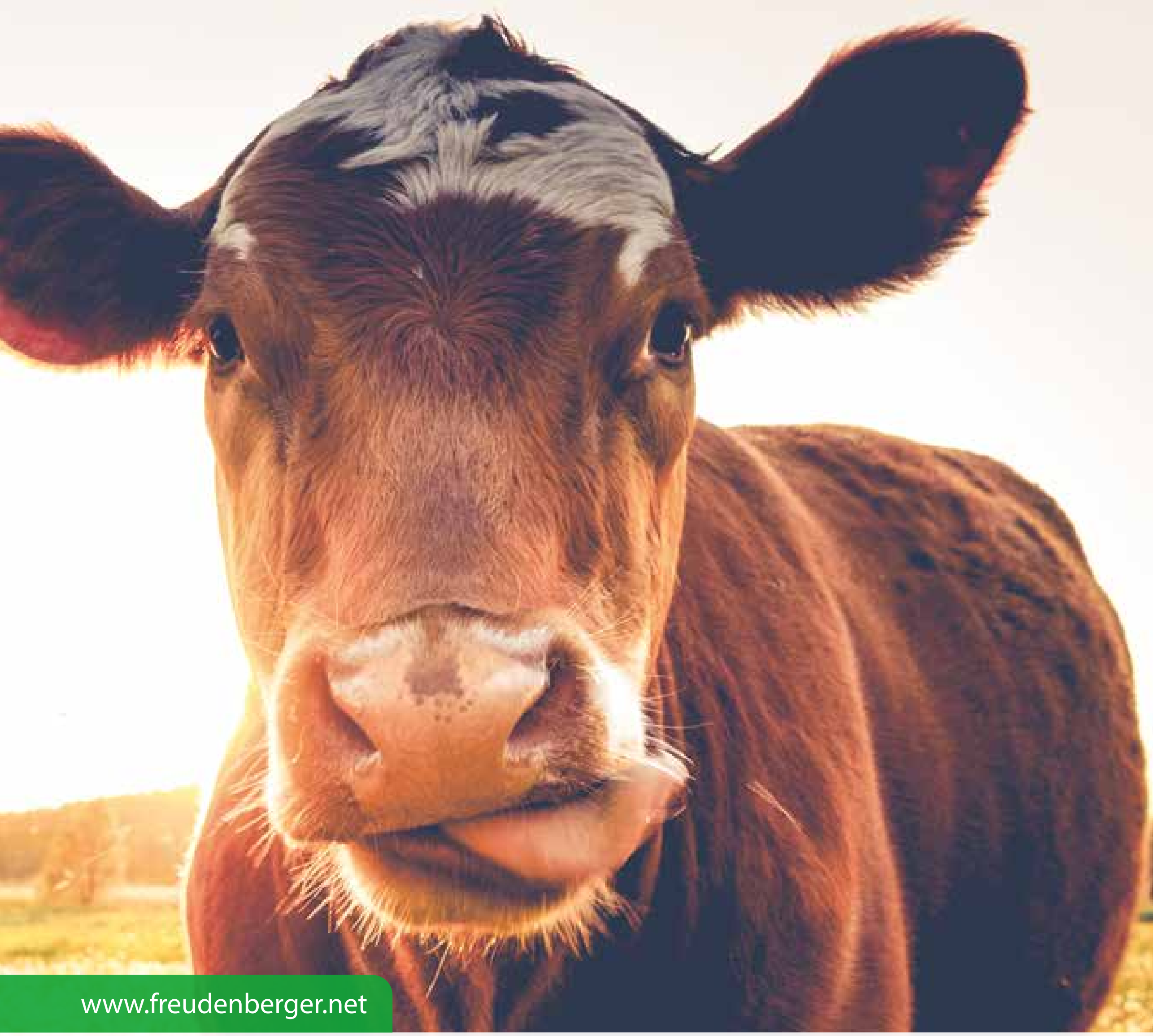

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The Freudenberger Grassland Book

A practical guide
to grassland management

FELDSAATEN · FREUDENBERGER ·

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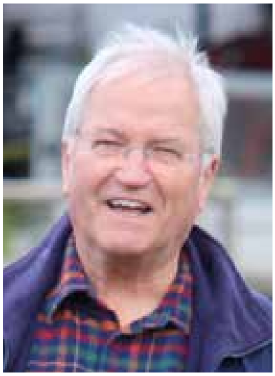
Dear Reader,



For more than 75 years and three generations, we at Feldsaaten Freudenberger have distributed seeds around the world. Everything began in 1948 with a few clover seeds and a bicycle. The seeds have now grown into thousands of different products and the bicycle has gone into well-deserved retirement. Since those first years, seeds for fodder production have played a central role in our company, especially those used in grassland systems.

All this time has also taught us a lot about proper grassland management and allowed us to build up a comprehensive body of knowledge. We regularly receive questions from farmers and customers on matters relating to grasslands, which we are always happy to answer.

In this book, we have tried to condense our know-how into a compact, easy-to-understand form. It's our way of being at your side when you need a question answered or a helping hand, a guide for your day-to-day work on your grassland. Faced with massive economic pressures, farmers are forced to minimise production costs while optimising yield. Forage offers considerable potential that often goes overlooked, and which can be mobilised with proper management.

We have set ourselves the task of covering every area of grassland management in this book and bringing together the most important information. Naturally, there are vast amounts of additional information available on each of the topics covered, but we have tried to focus on the essentials.

We hope that this book has something for you as well!

Wishing you an enjoyable read,

Manfred Freudenberger
CEO, Feldsaaten Freudenberger GmbH & Co. KG

THE IMPORTANT BASICS...

...PUT INTO PRACTICE!

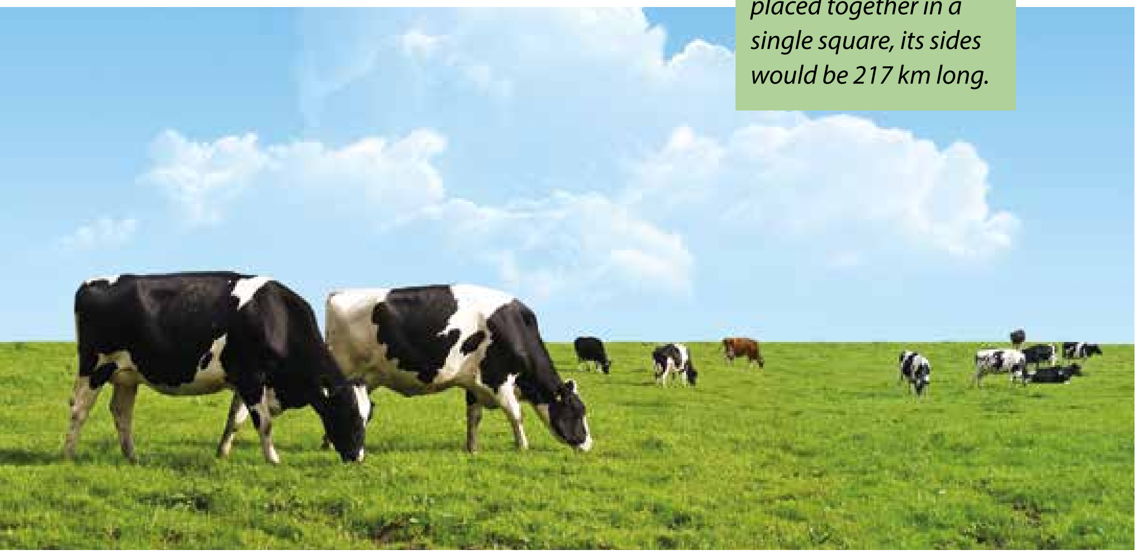
1 Introduction

1.1 Grasslands: What are they and where do they come from?

The term "grassland" refers to agricultural lands that are used permanently (permanent grassland) or over several years (temporary grassland). The term "pastureland" is also commonly used. Grasslands are an important component of the current agricultural landscape and first came about as a result of the domestication of farm animals. In recent years, the amount of space used in this manner in Germany has remained constant at around 4.7 million hectares, or 28% of the country's agricultural land. Due to the many functions for which grasslands are used, we often speak of their "multifunctional" role. Goals such as species diversity, preserving cultural landscapes, drinking water production and soil protection are some of the complementary effects that are sought in addition to the main aim, namely the production of high-quality forage.

Info

There are over 4.7 million hectares of grasslands in Germany. If these areas were placed together in a single square, its sides would be 217 km long.



A typical north German permanent pasture

1.2 How grasslands are used: meadows and pastures

The way in which grasslands are put to use is primarily influenced by the date on which they are utilised for grazing or cutting and the frequency (per year) of subsequent utilisation. Both of these aspects determine, to a significant extent, the grassland's capacity. Meadows tend to be characterised by low-intensity utilisation, primarily by mowing. The number of cuts per year varies depending on the different frequency and intensity of utilisation, but it generally ranges between one and seven. Pastures, by contrast, tend to see more frequent use, which most commonly takes the form of grazing. The dividing line between meadows and pastures is rather fluid, with intermediate grasslands often referred to as hay pastures. Even pastures exclusively used for grazing require mowing at regular intervals after being put to use, in order to prevent scrub encroachment and reduce weed growth. With growing intensity of use, the grassland's productivity steadily increases.

This meadow is ready for the next cut

Grassland management system		Form of use		Number of paddocks	Mowing	
Unregulated use	▶	Ranching	➡	No paddocks	No	**Recovery of fodder excesses arising periodically due to cutting**
		Continuous grazing	➡	1-3 paddocks		
Regulated use	▶	Short-grass grazing	➡	1 paddock with electric fence subdivision	Yes	**Recovery of fodder excesses arising periodically due to cutting**
		Grazing enclosure	➡	4-8 paddocks		
		Rotational grazing	➡	Over 8 paddocks		
		Ration grazing	➡	Daily allotment		

1.3 Short and tall grasses

If the different types of grassland utilisation are examined in greater detail, we find two main types of grasses that follow different strategies due to genetic adaptations. Short grasses are adapted to a high frequency of utilisation and can mobilise the energy needed for regeneration from the leaf area remaining after being cut or grazed. By contrast, tall grasses store their energy reserves in their stubble and roots, which only become available for the regeneration phase if the plants are allowed to grow before being grazed or cut.

As a result, tall grasses form very few low-lying leaves and invest their energy into long-term reserves. This genetic adaptation has given rise to the name "meadow type". They are known for their high yield and contribute significantly to the structure of forage. Timothy grass and meadow fescue are common grasses in this group and are frequently found in stands of meadow-type grasses. They will be discussed in greater detail in Chapter 2. Short grasses grow considerably more leaves close to the ground. Their adaptations have led to them being termed "pasture type".

They create a thick, stable sward of grass. Typical representatives of this group are perennial ryegrass and smooth-stalked meadow grass. The increasing intensity of utilisation (regular mowing or grazing) primarily supports the growth of short grasses through natural selection. This is because tall grasses are unable to store sufficient reserves within a short timeframe.

Short grass-heavy stands appear green right after mowing because of the remaining leaf mass.

Stands with a high portion of tall grasses typically have little leaf mass remaining after being mowed. Their reserves are stored in the roots and shoots.

2 Species of permanent and temporary grasslands

2.1 Distinguishing features

Being able to recognise individual species is an essential skill for assessing grassland areas. In general, grasses can be divided into two growth habits: those that form runners (also called sod-forming grasses) and those that form tufts (also called bunchgrasses). Grasses belonging to the first growth habit form a much thicker sward and can reproduce asexually through rhizomes or stolons (vegetative multiplication) as well as sexually via seeds. Bunchgrasses, on the other hand, only reproduce sexually. The most important distinguishing characteristic when identifying grasses is the arrangement of leaves in the youngest shoot (vernation), which may appear folded or rolled. Another important characteristic is the presence or absence of auricles and ligules, which are found on the upper side of the most widely opened leaf sheath. Both may be present with a different appearance. For example, all ryegrasses have clear auricles, while the ligules are only slightly developed. Cocksfoot, on the other hand, is an example of a grass with highly developed ligules. Additional characteristics for identification, including hairiness and the shape of the leaf blade (lamina) are shown in the illustration on the right. To be able to identify each species exactly, we recommend referring to a field guide such as Ulmer Verlag's *Taschenbuch der Gräser*.

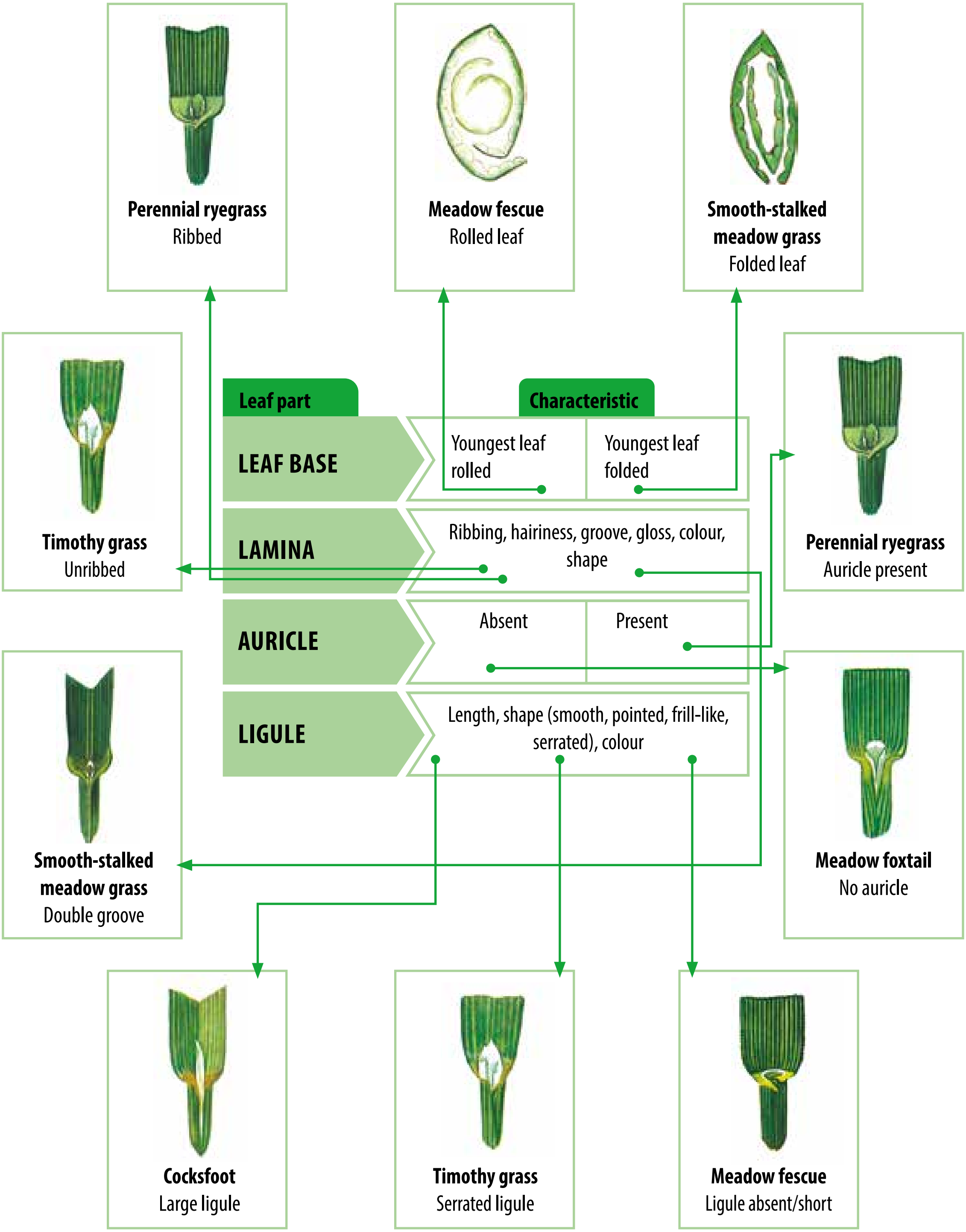
Note

Sod-forming grasses form above- or belowground runners, allowing them to multiply even without seeds. This makes smooth-stalked meadow grass an important component in grasslands in spite of how difficult it is to establish.

Tip

Approach to grass identification:

1. *Trait: youngest shoot (rolled/folded leaf arrangement)*
2. *Trait: Auricle/ligule (present/absent)*
3. *Trait: Leaf blade (ribbed, hairy, etc.)*


Perennial ryegrass
Ribbed
Meadow fescue
Rolled leaf
Smooth-stalked meadow grass
Folded leaf
Timothy grass
Unribbed
Leaf part
Characteristic
LEAF BASE
Youngest leaf rolled
Youngest leaf folded
LAMINA
Ribbing, hairiness, groove, gloss, colour, shape
AURICLE
Absent
Present
LIGULE
Length, shape (smooth, pointed, frill-like, serrated), colour
Perennial ryegrass
Auricle present
Smooth-stalked meadow grass
Double groove
Meadow foxtail
No auricle
Cocksfoot
Large ligule
Timothy grass
Serrated ligule
Meadow fescue
Ligule absent/short

2.2 High-quality grasses with feed values of 7-8

2.2.1 Perennial ryegrass (Lolium perenne)

Perennial ryegrass is the most important short grass for intensively utilised grassland sites. It is classed as extremely high quality, with the highest possible feed value of 8. It is characterised by a high sward density and persistence. In particular, its high competitive vigour makes it an absolute powerhouse for reseeding, especially when early-maturing varieties with rapid early development are used. Furthermore, perennial ryegrass is characterised by a high tolerance for trampling and good tillering. It is less well suited to sites with annual precipitation under 600 mm. Black frost and late frost also present problems for perennial ryegrass. High yields can be obtained with intensive fertiliser application. Due to its high regenerative capacity, perennial ryegrass is particularly at home on intensively utilised sites such as meadows that are cut multiple times or intensively grazed surfaces. The vast number of varieties available can be divided into different maturity groups. They can be further grouped into varying levels of disease resistance and particular growth patterns. Both diploid and tetraploid varieties are available, with the latter exhibiting higher digestibility, more vigorous early growth and better suitability for use as silage, albeit with greater water demand and a lower shoot and sward density.

Note

Without a doubt, perennial ryegrass is the most important component of intensive grassland sites. Furthermore, it is the only grass that is ideal for reseeding due to its tremendous competitive vigour. Here, especially, the use of Coated Seed can offer many advantages, chief among them being better soil contact, reliable early growth and reduced susceptibility to diseases. For additional information, please see Chapter 5.3 Reseeding.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Folded	Grooved top surface, very smooth bottom surface	Weak ligule, large auricle	Without awn	Reddish shoot base
In comparison	Italian ryegrass: Shoot rolled, awned spikes			

2.2.2 Italian ryegrass (Lolium multiflorum)

Unlike perennial ryegrass, Italian ryegrass is primarily used in field forage production since it is less persistent and can only be used for 1-3 years. Directly after sowing, it exhibits a high competitive ability. The species comes from the Mediterranean region, which is why it is known as 'Italian ryegrass'. With a feed value of 7, Italian ryegrass is one of the highest-quality tall grasses, producing very high yields with intensive fertiliser application and cutting.

The first growth offers a comparatively high level of leaf mass, while subsequent regrowth contains a higher proportion of stalks. Italian ryegrass is better suited to growing on moist sites, with a notable sensitivity to harsh conditions and drought-prone regions. The high productivity of Italian ryegrass is particularly evident when it is used in field forage production.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Grooved top surface, very smooth bottom surface	Weak ligule, large auricle	Awned	Reddish shoot base

2.2.3 Meadow fescue (Festuca pratensis)

Meadow fescue is a tuft-forming tall grass which stands out primarily for its extreme winter hardiness. As such, it can function as the main stand-forming species alongside Timothy grass after very strong winters. With a feed value of 8, it is comparable to perennial ryegrass owing to its extremely leafy structure. Meadow fescue tolerates medium cropping and fertiliser application and works well for fresh, moderately utilised meadows. It exhibits rapid early development. Its competitive ability against more vigorous species, such as perennial ryegrass, is less prominent. In four-cut systems, the yield levels and fodder quality of meadow fescue is comparable with that of perennial ryegrass. Festulolium is known as an intergeneric hybrid of Festuca and Lolium. The objective of the hybridisation was to combine the advantages of both species.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Grooved top surface, very smooth bottom surface	Short ligule, small auricles	Without awn	Reddish shoot base

2.2.4 **Smooth-stalked meadow grass** (Poa pratensis)

Smooth-stalked meadow grasses produce underground runners in order to develop extremely high sward density. At the same time, they are also very trample-resistant. This short grass, with a feed value of 8, is also very winter-hardy and extremely persistent. It is particularly suitable for dry locations with intensive utilisation, which is highly desirable on areas such as hay pastures or grazing pastures. Only heavy, cold soils are less suitable for the species. One problematic aspect of smooth-stalked meadow grass is its very slow early development, which reduces its competitive ability considerably. This can result in its full yield potential only being realised after several years of growth. Even so, smooth-stalked meadow grass is an essential component of pasture and meadow mixtures for its role in sward formation.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Folded	Cymbiform (boat-shaped) acuminate, prominent middle vein, lower side smooth	Small ligule No auricle	Panicle with five branches per head	Shoot base with underground runners

2.2.5 **Timothy grass** (Phleum pratense)

Timothy grass is a tuft-forming tall grass with a very late flowering period. With a feed value of 8, it is suitable for both meadows and pastures. The species also tolerates multiple cuts, although subsequent growth is rated as rather weak. It is extraordinarily winter-hardy and persistent, though it is frequently displaced due to its low competitive vigour. Moist to wet sites are preferred, with a marked sensitivity to long-lasting droughts. Timothy grass can be distinguished from the morphologically similar meadow foxtail through the hornlike spikelets, serrated ligule and late flowering, as opposed to the single, long awn and early flowering in meadow foxtail.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Leaf underside smooth	Large ligule, serrated and white with "corner teeth" on either side No auricle	Cylindrical spike with 2 horns per spikelet	Base onion-like

2.2.6 **Meadow foxtail** (Alopecurus pratensis)

Like Timothy grass, meadow foxtail is a tall grass, though it flowers very early and is primarily found in moist, nutrient-rich meadows. Meadow foxtail is not generally encountered on dry sites or pastures. Its slow early development means that it only shows its full yield potential in its second year of growth. With a value of 7, its quality is very high. Meadow foxtail is quite persistent, especially when cut early in the season. High yields and four cuts per season can be achieved under intensive fertiliser application. Meadow foxtail tolerates moderate shading, which often occurs on moist meadows at forest edges. It also deals well with persistent cold periods and snow cover.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Ribbed, central stripes without ribs	No auricles, green ligule (truncate)	Cylindrical spike with one awn per spikelet	Flowers early

2.2.7 **Cocksfoot** (Dactylis glomerata)

Cocksfoot is an extensive tuft-forming tall grass and has a feed value of 7 when cropped early. Due to early sprouting and premature lignification, delays in cutting or grazing decrease the value considerably. Cocksfoot is persistent and highly competitive, with strong mass formation and strong first growth and regrowth. It is considered ideal for dry places and is resistant to cold. It can tolerate intensive levels of fertilisation and cutting, as well as grazing. The variety can be used for 4-6 grazing cycles and be mowed 3-4 times. Persistent wet conditions and standing water should be avoided. Like other species, cocksfoot only reaches its full yield potential in the second year of growth.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Folded	Unribbed, strong leaf shoot	No auricle, long ligule	One spikelet per attachment point	Base onion-like

2.3 Additional species with feed values 3-7 for specific site characteristics

2.3.1 **False oat-grass** (Arrhenatherum elatius)

False oat-grass belongs to the group of tall grasses and is not suitable for grazing as a typical meadow grass. In spite of its feed value of 7, it is infrequently cultivated. False oat-grass forms loose, tall tufts that generally do not have too many leaves. On harsh sites, especially ones with late frosts, it is easily winterkilled. Its deep, strong root penetration is a key characteristic of the species and significantly reduces its susceptibility to droughts. False oat-grass sprouts early and exhibits rapid early development, resulting in good competitive vigour compared to other plants. Typical meadows of false oat-grass can tolerate 3-4 cuts and achieve high yields. Due to the bitter saponins it contains, it can only be used sparingly in silage.

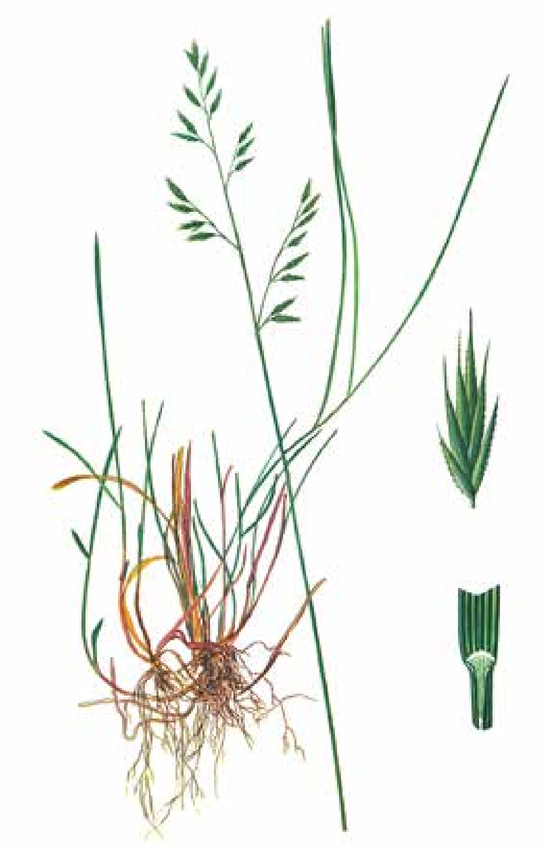
Note

False oat-grass is thoroughly recommended for planting due to its feed value of 7. Especially in very dry sites, cultivation of false oat-grass can be advantageous due to its deep-reaching root system, which allows it to withstand even long dry periods. These factors make false oat-grass a typical component of extensive grassland systems.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Slightly hairy upper sheath	No auricles, large ligules, margin fringed	One "geniculate" awn per spikelet	-

2.3.2 **Red fescue** (Festuca rubra)

Red fescue is a short grass that can be divided into two subspecies, one of which is tuft-forming and can be found in meadows, while the sod-forming subspecies is used in pastures. Only sod-forming varieties of red fescue are available for agricultural use. These varieties are known for their good persistence and excellent winter hardiness. They are effective at closing gaps in the sward and can tolerate intense grazing well. This also increases the rate of growth. Red fescue is less at home on marginal sites, especially ones that are too dry, too wet or nutrient-poor. Although it only has a feed value of 5, it is indispensable on many sites due to its persistence and undemanding nature.



Leaf base	Lamina	Leaf node	Inflorescence	Other features
Folded (sometimes bristle-shaped)	Prominently ribbed, narrow	No auricles, ligules very short	No awns, blooms red	Shoot base brown

2.3.3 Common bent (Agrostis capillaris)

Common bent is commonly found in harsh environments and marginal sites. It forms underground runners, which leads to a very thick sward. The feed value is quite low, at 5. However, the species is one of the most important meadow and pasture grasses in mountainous regions.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Ribbed, glabrous (hairless)	No auricles, ligule truncate	Aristate, reddish hue	Shoot base forms runners

2.3.4 **Soft brome** (Bromus hordeaceus)

Soft brome is considered a medium grass and does not form tufts. Because of its pronounced hairiness, the plant has an extremely low feed value (3). Ruminants avoid consuming it when they have the option to. Soft brome is a very early-maturing grass and grows especially well in grasslands with gaps and a late cutting date. It does not tolerate grazing.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Contains soft hairs	No auricles, ligule short	Long awns	Densely hairy leaf sheath

2.3.5 **Yorkshire fog** (Holcus lanatus)

Yorkshire fog is a tall grass that forms tufts. Its rather low feed value of 4 is due to its hairiness and low digestibility. A persistent species, it prefers moist, acidic and nutrient-poor soils.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Contains soft, dense hairs	No auricles, large ligules, deeply frayed	Reddish hue	Shoot base has red-violet veins

2.4 Legumes in grasslands

Legumes possess the unique ability to introduce nitrogen into the soil with the aid of rhizobia. Deep-rooted species, especially alfalfa and red clover, are able to combat soil compaction, outlast dry spells and tap nutrients in danger of leaching into groundwater. Year-round shading helps to suppress weeds and increase biological activity. No added nitrogen is necessary when planting alfalfa or clover due to their ample biological N fixation. Only a few plants are able to enter into a symbiotic relationship with nitrogen-fixing bacteria and thus use atmospheric nitrogen for plant growth. This symbiosis between leguminous plants and various strains of bacteria involves reducing atmospheric nitrogen (N_2) to ammonia through a microbiological process that uses the nitrogenase enzyme and energy. Studies have reported rates of N fixation of 50-700 kg N/ha/year. In planted mixtures, any N additions should be based on the share of clover in the mixture (see table below). In grasslands, a clover share of 15-20% can provide long-lasting improvements to yield and quality, while also reducing the required expenditures on fertiliser. In field forage systems, alfalfa and clover have highly positive effects on cereals, sugar beets, potatoes and maize when grown as prior crops. Cultivation intervals of 4-7 years, however, should be observed due to nematodes, sclerotinia and ring rot disease.

N fertiliser requirements of clover-grass mixtures

Clover percentage		
0–10%	**10–30%**	**> 30%**
N application as in grasses	Up to 50% of N application	No N application

Grassland with a high share of white clover (> 30%)

2.4.1 **White clover** (Trifolium repens)

White clover is a persistent, low-growing clover species. It is very widely cultivated and has earned top grades in fodder quality (feed value 8). It is very well suited for intensive grazing areas, due in particular to its adaptability, winter hardiness, tolerance to being trampled and repeatedly cut, as well as its ability to grow back. It is only somewhat suited for use in meadows, due to its low growth habit. White clover forms aboveground runners, which make it especially good at closing gaps. In general, clover species are less demanding in terms of climate and soil characteristics. All clover species have high water requirements and therefore tend to be best suited to cool and wet areas. White clover is considered particularly undemanding in terms of soil, though it is sensitive to drought and cold. It is therefore not tolerant of very dry sites. The varieties available can be distinguished based on their maturity group, yield level and winter hardiness. In addition to its creeping, runner-forming growth habit, white clover can be recognised by its oval to round leaves. Most leaves have a whitish spot and a serrate margin.

2.4.2 **Red clover** (Trifolium pratense)

As an annual or multi-year plant, red clover is found less commonly in permanent grasslands than white clover and is instead planted more frequently in field forage systems. It can also be grown on extensive grasslands with lower intensity of utilisation. Recent studies have shown that planting red clover offers a multitude of benefits, even when added to existing permanent pasturelands.

MERULA, a Mattenklee-type red clover

Red clover is very leafy and is a high-quality feed component, with a feed value of 7. Two cuts can take place in the year in which direct seeding occurs. In the next year, it can tolerate up to four cuts per year if they take place during the bud stage. For multi-year use, cultivation in a mixture with grasses is recommended. In these cases, a reduction in the amount of clover in the stand can be observed over time. Red clover forms a clear taproot and prefers loams to heavy soils. Sufficient water supply must be ensured. The varieties available can be divided into two groups. The more commonly used "normal" red clover varieties consist of different maturity groups. These varieties tolerate multiple cuts and are characterised by rapid regrowth after mowing, such that subsequent cuts offer good yields. The second group consists of "late" red clover varieties, which can only be cut once as subsequent growth is quite weak. Varieties in this group tend to bloom late; the overall yield is considerably lower than in normal red clover varieties. Apart from being grouped according to their maturity group and ploidy level, the available varieties are also classified based on their susceptibility to mildew, sclerotinia and anthracnose.

Info

What is Mattenklee?

For over a century, Swiss farmers have been planting Dutch red clover varieties in their high-altitude fields. After being put to use for three years, the seeds are collected from the surviving red clover plants in the fourth year for the next year's planting. This has led to the spontaneous selection of extremely persistent landraces. To this day, modern Swiss plant breeders continue this legacy with their Mattenklee varieties. These persistent varieties exhibit a clear advantage in terms of their establishment in permanent grasslands.

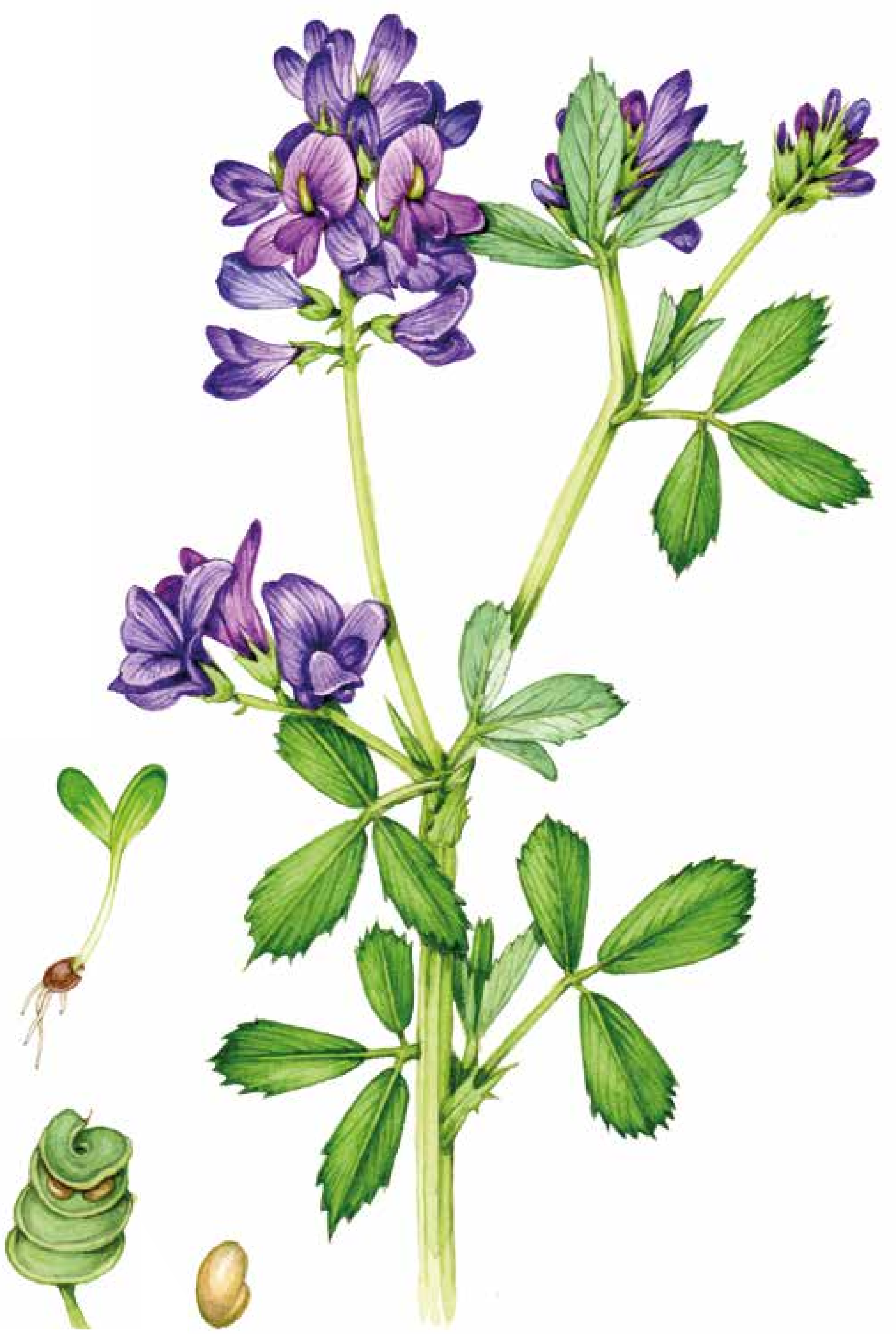
2.4.3 Alfalfa (Medicago sativa)

Alfalfa (lucerne) is a fodder plant known for its high yield and protein content as well as its role in improving the soil. It is often referred to as the "queen of fodder plants". It is characterised by a taproot that grows up to 2 m in length and is winter-hardy (-20°C). Nowadays, alfalfa is primarily cultivated as an annual or biennial plant, though it is sometimes allowed to grow for three years. It is often found in mixtures with grasses, much like red clover. It should be noted that when planted for multiple years, the plants must be allowed to flower once per year. Alfalfa prefers deep loamy soils in warm regions with a dry summer period. In general, it is able to tolerate drought better than red clover. Soil that can be easily penetrated by roots and pH ranging from 6.5-7.5 (depending on the soil type) are both good for growth. The fodder plant's climatic needs are characterised by a high demand for water, heat and sun. Unfavourable sites for alfalfa include cool north-facing slopes and soils that are acidic, difficult for roots to penetrate, or affected by standing water or moving groundwater. Compacted and depleted soils also hinder growth. Weed pressure should be kept as low as possible due to alfalfa's low competitive ability during its early growth.

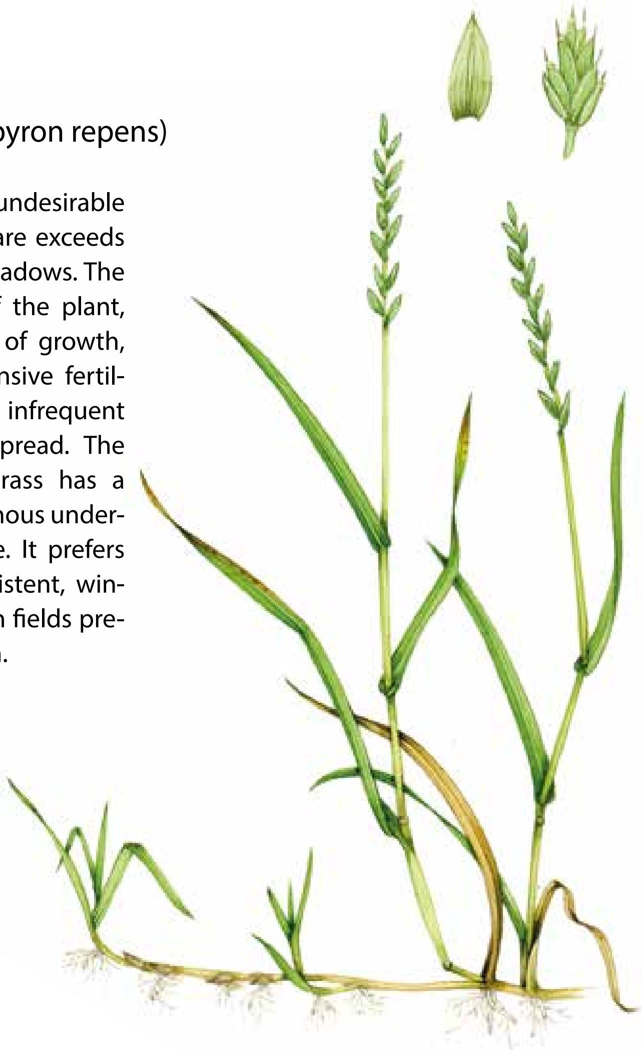
Note

Compared to other fodder crops, alfalfa and clover are primarily distinguished by their high protein and mineral content as well as their reliable yields. As native sources of protein-rich fodder, they can therefore help reduce imports of protein feed such as soya beans. Alfalfa and red clover can therefore be used in ruminant fodder as protein sources as well as for the structural benefits they provide. The high feed value of 8 is further supported by high phosphorus, calcium and magnesium content.

PLATO alfalfa-grass mixture (with 70% alfalfa)



2.5 Undesirable grasses in pasturelands



2.5.1 Couch grass (Agropyron repens)

Couch grass is considered an undesirable grass species as soon as its share exceeds 10% on pastures or 30% on meadows. The hairiness and intense smell of the plant, especially during later phases of growth, lead to it being avoided. Intensive fertiliser application combined with infrequent grazing or mowing help it spread. The low-growing species couch grass has a feed value of 6 and forms enormous underground runners to multiplicate. It prefers moist to wet sites and is persistent, winter-hardy, and is often found on fields previously used for crop cultivation.

Control

Couch grass can be suppressed by increasing the frequency of mowing or grazing or by reducing or shifting fertiliser applications in the second half of the year. After a period of grazing, mowing is essential.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Rolled	Mostly hairy, leaves often twisted, blue-green	Prominent auricles (pointed), short ligule	Mostly without awns, spikelets arranged terminally on the axis	Multiplication via rhizomes
In comparison	Spikelets in perennial and Italian ryegrass have the narrow side on the axis			

2.5.2 **Rough-stalked meadow grass** (Poa trivialis)

Rough-stalked meadow grass is a persistent short grass species with aboveground runners. It is winter-hardy, can tolerate trampling and biting, and is known for aggressively filling gaps. When not present in abundance, it is classified as high-quality forage with a feed value of 7 in its first growth.

It is considered tolerable when its share of pastures lies below 10%, or 15% in meadows. Its feed value drops sharply (4) when it is present in greater amounts due to its musty smell and the matted sward it produces. It generally appears following improper management practices (overgrazing, low cutting, soil compaction) in wet years. It does not tolerate drought at all.

Control

Choosing the right cutting height helps more valuable grasses to outcompete rough-stalked meadow grass. Shoots from runners can be reduced by cutting low every 2-3 years and deep harrowing during dry weather.

Leaf base	Lamina	Leaf node	Inflorescence	Other features
Folded	Finely pointed, double groove in middle Smooth bottom surface	No auricles, pointed ligule	Panicle with five branches per head	Multiplication by aboveground runners
In comparison	Pointed lamina (smooth-stalked meadow grass: boat-shaped), ligule larger and more pointed than smooth-stalked meadow grass			

2.6 Poisonous plants – What makes them poisonous?

During the massive intensification of grassland management in the 1960s to 1990s, poisonous plants were hardly a concern. It was only with the increase in extensification and the larger number of nature conservation areas that we begin to see the appearance of undesirable species. Especially in areas that see very low-intensity utilisation, with the first (sometimes only) cut coming very late, there is a danger that the beneficial biodiversity will be accompanied by the growth and multiplication of poisonous plants. Additionally, some of the species of concern may also be protected by conservation measures, meaning that control practices will be highly limited or even prohibited. Poisonous plants can often be recognised by the production of various secondary compounds that the plant has evolved to produce as a repellent. Glycosides, alkaloids and tannins are some of the most important examples of these substances.

Common ragwort in a grassland

2.6.1 **Common ragwort** (Senecio jacobaea)

Common ragwort belongs to the aster family and prefers poor, extensive grasslands. It is particularly common on temporarily dry and calcareous soils. Fallow grasslands and horse meadows are the most severely affected. Common ragwort produces yellow flowers from June to September and grows to a height of 120 cm.

Older plants are generally avoided, but younger ones are commonly consumed, even though they are the most poisonous. The alkaloids they contain remain present even in hay or silage preparations. They tend to affect ruminants less severely than horses.

Control

Early cutting is the most effective way to prevent multiplication. In addition, gaps and trampling damage should be prevented as much as possible. Individual plants should be uprooted and removed completely from the area. Any gaps should be reseeded immediately.

2.6.2 **Autumn crocus** (Colchicum autumnale)

The autumn crocus prefers moist to wet meadows that are cut late in the season and have deep, nutrient rich soil. Due to its vulnerability to trampling, it is more likely to appear on meadows cut 2-3 times per season. Late cutting dates after June 15 are extremely favourable for autumn crocus multiplication. The plant forms a deep-lying corm and can grow to heights of 8-40 cm. All parts of the plant contain high amounts of colchicin, a toxin, and other alkaloids. Inexperienced juvenile animals are at the greatest danger of consuming the poison while feeding. It should be noted that the toxin remains present even in hay or silage. In fully grown horses and cows, 1.5 to 2.5 kg of fresh matter can be deadly.

Control

Early cuts and timely grazing are the most effective ways to prevent multiplication. In addition, gaps in the grassland should be avoided as much as possible. In general, grazing has a highly beneficial effect due to the plant's susceptibility to trampling.

2.6.3 **Rattle** (Rhinanthus sp.)

Rattles are frequently found in moist areas with late cutting or mowing dates on which fertiliser application has been drastically reduced in the recent past (conventional fields being transitioned to organic cultivation). Rattles are hemiparasites and impair the growth of the grasses growing in the pasture or meadow. Its poison is mostly present in its seeds. With as few as 10 plants per square metre (a share of around 3%), it can cause reduced yields.

Control

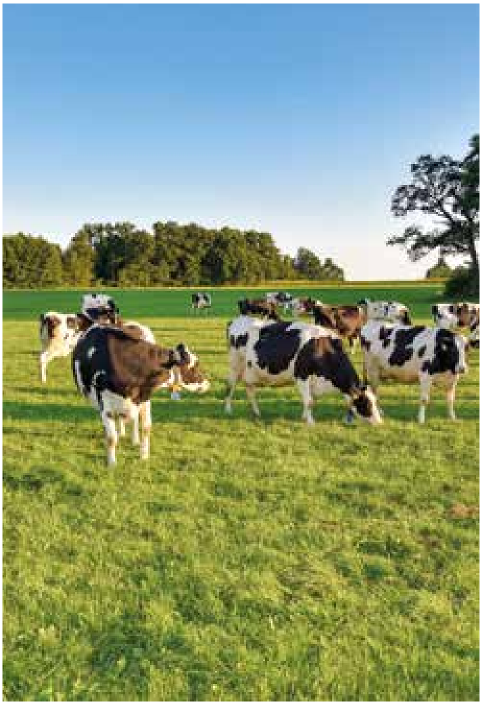
Multiplication can be slowed primarily by early cutting or grazing, but also by applying a nitrogen-rich fertiliser.

3 Typical plant communities in grasslands

As discussed in the previous chapters, permanent grasslands are comprised of different species of plants and can contain varying numbers of plant species depending on the site characteristics and management aims. The plant population is made up of species with different growth habits, which can be combined into a series of plant communities. These communities form the basis of the site's production capacity. This chapter will present four of the most common plant communities, the manner in which they are utilised and their special characteristics. This will help us to identify and appraise grasslands later on. It should be noted that the plants which give the community its name do not necessarily need to feature prominently or even necessarily be present.

3.1 Ryegrass-white clover pastures

Ryegrass-white clover pastures, sometimes referred to as "rich pastures", are characterised by grass-rich and species-poor stands. The main components of these pastures are perennial ryegrass and white clover. Species like smooth-stalked meadow grass, Timothy grass and bentgrass are also common. Herbaceous species such as plantains, daisies and the creeping buttercup are well-suited to the community. Grasslands of this type are dependent on ample rainfall and a good water supply more generally. High-intensity utilisation, good nutrient supply and grazing are all conducive to these plant communities, with early first cuts showing a particularly positive effect. Established stands of these plants are typically incredibly productive grasslands, with high-quality, hard-wearing and thick swards.



3.2 Red fescue-bentgrass pastures

The second common plant community in pasturelands is a red fescue-bentgrass association. Its distribution is distinct from that of ryegrass-clover pastures due to the plants' short growing period, very good winter hardiness and tolerance of nutrient-poor conditions. Since the dividing line between the two communities is rather fluid, a wide variety of intermediate forms can be observed. In addition to the eponymous red fescue and bentgrass, indicator species of nutrient-poor soils such as sweet vernal grass and Yorkshire fog are also present. Marsh foxtail is a typical indicator of wet conditions. The ecological value of these diverse plant communities is considerably higher than that of rich pastures with their lower numbers of species. At the same time, however, the biomass production of these pastures tends to be much lower.

3.3 False oat-grass meadows

False oat-grass meadows are common types of managed grasslands. They can be divided into dry, typical and wet meadows. As with other plant communities, the dividing lines between these types are fluid. Dry false oat-grass meadows are the most extensive form and generally allow only 1-2 cuts, with hay cuts being an option. In addition to false oat-grass, typical species of these meadows include cocksfoot, erect and soft brome, meadow sage, bird's-foot trefoil, daisy and black medick. Rattle is a commonly found species, though it is undesirable. With occasional applications of livestock manure, yields of 5,000 and 7,000 kg DM/ha are possible. Adding too much nitrogen may lead to the spreading of cow parsley and hogweed.

Typical false oat-grass meadows can be cut up to 3 times; good water supply is crucial. Smooth-stalked meadow grass, meadow fescue, red fescue, autumn dandelion, yarrow and spreading bellflower are common species in these meadows. On wet false oat-grass meadows, meadow foxtail often takes the place of false oat-grass. Additional common species on these meadows include the cabbage thistle, salad burnet, campions and Yorkshire fog. Good water supply makes it possible to increase the intensity of management.

3.4 Yellow oatgrass meadows

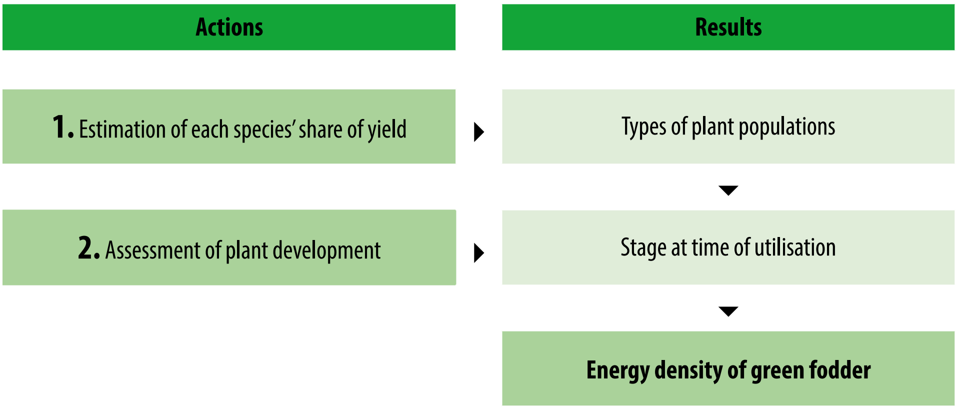
Yellow oatgrass meadows, known in some regions as rich alpine meadows (*Bergfettwiesen*), are found at higher altitudes, necessitating the replacement of false oat-grass. Yellow oatgrass meadows are especially common above 600 m.

The transition between yellow oatgrass and false oat-grass meadows, however, is fluid and the two cannot be neatly divided based on altitude alone. In addition to yellow oatgrass, typical species include smooth-stalked meadow grass, meadow fescue and cocksfoot, as well as herbs like alpine knotweed, narrow-leaved narcissus and rough hawksbeard. Yellow oatgrass meadows are highly biodiverse and have an extremely high ecological value. The species richness can be maintained by mowing in early summer and in autumn. With high shares of yellow oatgrass (> 25%) pastured animals may run the risk of contracting the metabolic disease calcinosis. Increasing the intensity of cutting or grazing can suppress yellow oatgrass. A continuous depletion of the soil may lead to the encroachment of acidic or calcareous grasslands, depending on the type of subsoil.

4 Grassland management: Fodder collection

4.1 Assessing grasslands and estimating feed value

The DLG key for coarse feed evaluation has proven to be an effective tool for assessing grassland stocks and the resulting feed value. This tool makes it possible to estimate the energy content of a grassland stock as a function of the plant population and stage at the time of cutting or grazing. It involves two simple steps:



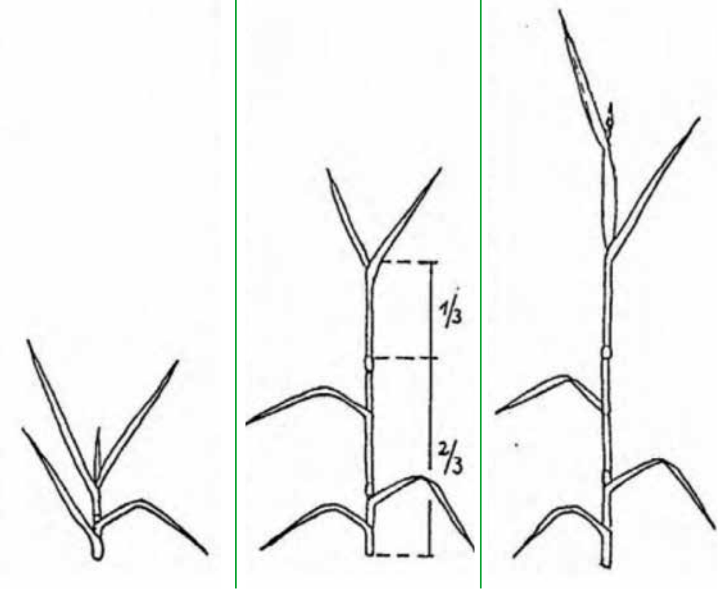
First, the percentage of yield represented by each plant species is estimated. This is done by choosing 3-4 representative points in the grassland area. Grassland populations are frequently quite heterogeneous, with individual grasses exhibiting highly variable levels of abundance over the space. It is important that the parcels chosen represent the area as a whole. Normally, a circle with a radius of around 5 m is sufficient to estimate the type and percentage of each plant species.

Grasslands are generally divided into grass-rich, herb-rich and balanced populations. The highest energy concentrations occur in ryegrass-rich grassland populations. The lowest energy concentrations are found in areas with high concentrations of herbs and grasses with a low feed value. Completely balanced stands most often tend to exhibit an intermediate energy concentration.

Grass share	Type of stand	Symbol
Grass-rich (> 70% grasses)	**Ryegrass-rich** (short grasses) Predominantly ryegrasses or meadow grasses	G_1
	Not ryegrass-rich (tall grasses) e.g. cocksfoot, foxtail, meadow fescue, false oat-grass, yellow oatgrass	G_2
Balanced (50-70% grasses)	**Fine-leaved** herb and clover species, among grasses short grasses predominate	A_1
	Coarse-leaved herb and clover species, among grasses tall grasses predominate	A_2
Clover or herb-rich (< 50% grasses)	**Fine-leaved** herb and clover species, among grasses short grasses predominate	K_1
	Coarse-leaved herb and clover species, among grasses tall grasses predominate	K_2

In the second step, we determine the growth stage at the time of utilisation. Cocksfoot, if present, serves as a guide for grasses in this calculation. Otherwise, the main grass species in the stand can be used as a guide. For herbs, the growth stage can be determined based on dandelions. For regrowth, the growth stage is determined based on a calendar calculation, since regrowth following a cut generally does not enter a reproductive phase (flowering).

Grassland with a high share of white clover. According to the formula above, it would be identified as group A_1.



	I	II	III
Stage at time of utilisation	**Shoots**	**Prior to spike/panicle emergence**	**Beginning of spike/ panicle emergence**
Dandelion	Beginning of flowering, 1/4 of plants have flowered	All plants have flowered, 1/4 of flowers withered	All plants have flowered, 1/4 with seeds
Cocksfoot	Highest node of stalk 10 cm above the ground	Base of flowering site 2/3 up the stalk	Top of panicle begins to emerge from the leaf sheath

IV	V	VI	VII
End of spike/panicle emergence	**Flowering**	**After flowering**	**Beginning of seed maturity**
All plants have seeds	Only empty flower bases remain	Flower bases withered or fallen off	
Panicle fully emerged, full stalk height not yet reached	Full stalk height reached	Faded, stalk still green	Stalk yellow, seed husks fall off if struck with the hand

Based on the plant population and the determined growth stage, the following table can be used as a guide to the energy content of the forage.

Energy concentration (in MJ/kg DM) in green forage

Type of stand		G_1		G_2		A_1		A_2		K_1		K_2	
Maturity stage of first growth		ME	NEL	ME	NEL	ME	NEL	ME	NEL	ME	NEL	ME	NEL
I	Shoots	12.0	7.2	11.7	7.0	12.0	7.2	11.7	7.0	11.7	7.0	11.2	6.7
II	Before spike emerg. *)	11.7	7.0	11.2	6.7	11.7	7.0	11.3	6.8	11.3	6.8	10.8	6.5
III	Start of spike emerg. *)	11.2	6.7	10.5	6.3	11.2	6.7	10.7	6.4	11.0	6.6	10.5	6.3
IV	End of spike emerg.*)	10.7	6.4	9.8	5.9	10.7	6.4	10.0	6.0	10.5	6.3	9.8	5.9
V	Flowering	10.0	6.0	9.2	5.5	10.2	6.1	9.3	5.6	10.0	6.0	9.2	5.5
VI	After flowering	9.2	5.5	8.3	5.0	9.5	5.7	8.7	5.2	9.5	5.7	8.5	5.1
VII	Start of seed maturity	8.3	5.0	7.5	4.5	8.8	5.3	8.0	4.8	9.0	5.4	7.7	4.6
Regrowth													
Age in weeks													
	< 4	10.7	6.4	10.3	6.2	10.8	6.5	10.5	6.3	10.8	6.5	10.5	6.3
	4-6	10.3	6.2	10.0	6.0	10.5	6.3	10.2	6.1	10.5	6.3	10.0	6.0
	7-9	9.8	5.9	9.5	5.7	10.0	6.0	9.7	5.8	10.0	6.0	9.5	5.7
	> 9	9.3	5.6	9.5	5.4	9.5	5.7	9.2	5.5	9.3	5.6	9.0	5.4
ME = Metabolisable energy													
NEL = Net energy lactation													

**) Spike and panicle emergence*

4.2 Optimal cutting time: A matter of quality and biomass yield

As fodder plants age, their soluble carbohydrate (sugar) content increases. In both grasses and legumes, however, this figure drops back down beginning with the emergence of spikes/panicles prior to budding. During this stage of development, the protein content drops as well. The optimal cutting time during the first growth in grasses is therefore during the spike/panicle emergence stage, when plants have a crude fibre content of 21-23% DM. Legumes exhibit a greater flexibility with respect to cutting time, since their energy content decreases more slowly. The optimal time lies between the budding stage and the beginning of flowering. Because of the changed leaf/stem ratio, the harvest time for regrowth can be organised more flexibly.

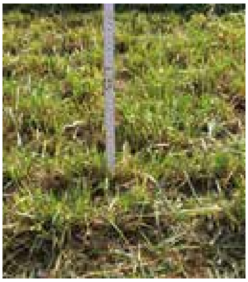
Info

Optimal cutting time: Beginning of spike emergence, with crude fibre at 22% DM.

4.3 Cutting at the right height decreases contamination and supports regrowth

In mowing processes, the cutting height and the settings used in the harvesting equipment are of particular importance due to their effect on the rates of contamination, measured as raw ash content (XA). In addition to reducing contamination, rapid regeneration of the grassland should be ensured. High raw ash content can lead to considerable reduction in the suitability for silaging. It also affects the feed value, since the energy concentration is lower at higher raw ash concentrations. Low cuts are known to result in higher raw ash concentrations than higher cuts. In addition, raw ash content increases from the first to fourth regrowth.

Cutting height 4 cm



Cutting height 7 cm

Cutting height 10 cm

Info

7 cm is the optimal cutting height for high yields and high quality.

4.4 The wilting phase

In order to reach the ideal dry matter content of 30-40%, the wilting phase is of critical importance. When DM content is low, nutrient-containing effluent leaks out of the silage and causes fermentation losses. Furthermore, wet silage has a higher raw ash content and, consequently, more butyric acid bacteria. This results in a lower-quality fermentation process. On the other hand, increasing the dry matter content of silage simultaneously raises its sugar level. This provides an important input for lactic acid production, positively affecting the fermentation process by ensuring a rapid drop in pH. There can, however, be disadvantageous if the dry matter content of the wilting silage exceeds 40%, since frequent turning over leads to crumbling losses. This results in the loss of leaf area, leading to energy and protein losses. Long wilting phases that last several days should also be avoided, since they may cause increased respiration losses and hinder the compactibility of green forage. This leads to a delay in lactic acid fermentation while also increasing the risk of reheating during the removal phase, which can result in mould growth.

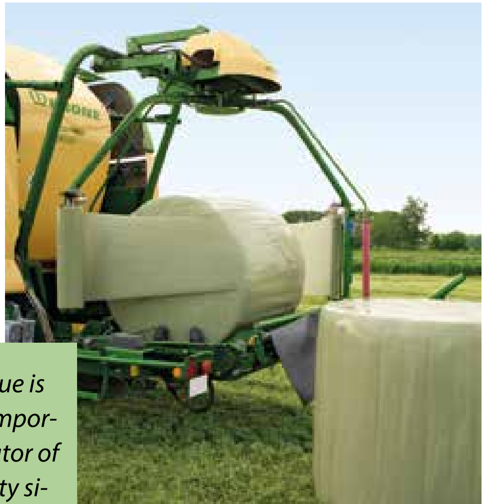
4.5 Fundamentals of silage preparation

The aim of silage preparation is to maintain the nutrient content of the fodder plants being preserved. High-quality silage can only be obtained if the fermentation process is predictable and elements that affect it negatively can be avoided. In particular, it is important to encourage desirable activity by lactic acid bacteria, since the lactic acid they produce helps preserve the fodder plants.

Silage preparation operates on the principle of changing plant-based carbohydrates (sugar) into organic acids under anaerobic conditions. This process involves reducing the pH value, which eliminates harmful bacteria. The following elements are indispensable for successful fermentation:

1. Sufficient moisture
2. High sugar content
3. Anaerobic conditions
4. Sufficient quantities of lactic acid bacteria

The most important elements for the fermentation process and the resulting quality are the pH value, the presence of fermenting acids, and the ammonia content relative to total nitrogen. The target values are listed in the table below. In principle, the silage should be free of butyric acid, since an excessively high acid component can lead to a reduction in the protein content and lower feed intake.



Info

The pH value is the most important indicator of high-quality silage with a long storage life.

Target parameters of good silage

Parameter	Unit	Target
pH value		4.0-5.0
Butyric acid content	g/kg DM	< 3
Acetic and propionic acid content	g/kg DM	20-30
Ammonia-N ratio	% of total N	< 8
Aerobic stability	Days	> 3

4.6 Fermentation processes

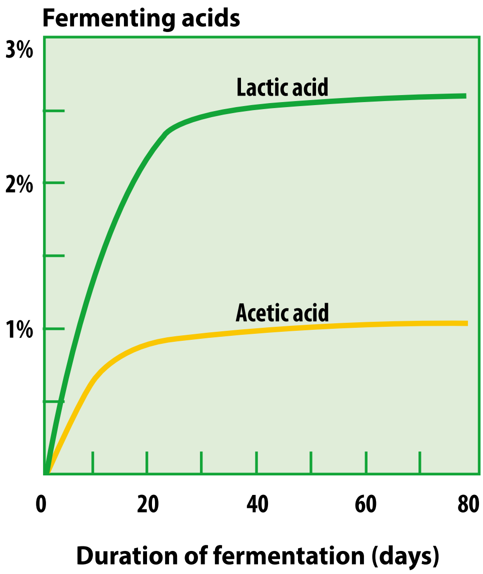
The process of making silage is divided into four phases. The first aerobic phase begins after the silo is filled and closed. This phase only lasts for a few hours. Carbohydrates are broken down through respiration, leading to the generation of heat, which indicates nutrient losses. The activity of aerobic microorganisms can only be halted by fully removing the air supply, which also stimulates the mass multiplication of beneficial lactic acid bacteria.

The second part of the fermentation procedure, the primary fermentation phase, usually lasts for a week. It is characterised by anaerobic activity in which plant tissues die and cell contents are released. Lactic acid bacteria compete with other microorganisms such as fermentation pests, butyric acid bacteria (Clostridium), acetic acid bacteria (Enterobacteria) and yeasts to use the limited available quantities of sugar as a nutrient source. High-quality fermentation depends on lactic acid bacteria almost entirely replacing undesirable microorganisms. Lactic acid bacteria cause an additional drop in pH to 4.5 through the generation of lactic acid. In comparison, the pH value at the beginning of the primary fermentation phase is around 6.5. The silage can be used in animal feed only once the primary fermentation is complete, which usually takes about 4 to 6 weeks.

The following third phase consists of the storage period. During this phase, most of the lactic acid bacteria die off. Their population shrinks to 0.1% of its initial total. With silage that contains sufficient fermentation substrate and sustained anaerobic conditions, this phase can theoretically last as long as desired.

In the fourth phase (removal phase), the compaction achieved during the storage period plays an important role. Aerobic conditions return to the exposed silo face. Depending on pore volume, which can be reduced by careful compaction, the penetration depth of oxygen is optimally no more than 1 m. In the areas where oxygen reaches, the growth of dormant microorganisms such as yeasts or mould spores is stimulated. This can result in the silage heating up and decomposing, a process known as faulty fermentation. In order to reduce the rate at which this occurs, a seasonally specific removal rate of 1.0 to 2.5 metres per week is crucial.

Progression of fermentation in a stable silage



4.7 Preservation capacity of various species

The suitability of fodder plants for silage is affected by both physical and chemical properties. The physical properties include water content, compactibility and drying speed. Biologically, the population of micro-organisms is a deciding factor. The chemical properties related to fermentation and preservation are dry matter content, buffer capacity, nitrate content and the amount of water-soluble carbohydrates.
Fermentability refers to the fodder plant-specific suitability for silaging. This is primarily affected by its dry matter (DM) content as well as the S/BC ratio, which is a measurement of the fodder plant's acidifying potential. This is calculated as a ratio of sugar content (S) to buffer capacity (BC). Both DM and the S/BC ratio are included in the fermentation coefficient (FC) using the formula FC = DM (%) + 8*S/BC. In general, good suitability for silaging comes with an S/BC ratio > 2.0 and an FC of > 45.0. Both red clover (1.7) and alfalfa (0.9) have S/BC ratios that are considerably lower than 2.0. Only pure ryegrass (3.3) can obtain the required value. Measured by its fermentation coefficient, ryegrass can exceed the required value when fresh (47.0) or wilted (62.0). The FC of wilted red clover (48.0) is considered good, while that of wilted alfalfa (42.0) is within the acceptable range. Fresh alfalfa and red clover cannot obtain sufficient values. It is clear, then, that both red clover and alfalfa belong to the group of plants for which silaging is difficult. Maize, in contrast, is often considered preferable from an economic standpoint and is suitable for silaging. The plant has an S/BC ratio of 6.6 and an FC of 75.0, which indicates high suitability for silaging.

Fodder plant	DM (%)	Sugar (g/kg DM)	Buffer capacity (g LA*/kg DM)	S/BC ratio	FC**
Ryegrass - fresh	20	173	52	3.3	47
Ryegrass - wilted	35	173	52	3.3	62
Red clover - fresh	20	115	69	1.7	33
Red clover - wilted	35	115	69	1.7	48
Alfalfa - fresh	20	65	74	0.9	27
Alfalfa - wilted	35	65	74	0.9	42
Legume-grass mixture - fresh	18	140	78	1.8	32
Legume-grass mixture - wilted	35	140	78	1.8	50
Silage maize (lactic ripeness)	22	230	35	6.6	75
Silage maize (wax-ripe stage)	30	110	32	3.4	58

**LA = Lactic acid ** FC = Fermentation coefficient*

Wilted legume-grass mixtures fulfil the requirements for good silaging.

In order to increase the suitability of leguminous plants for preservation, the use of mixtures such as clover-grass or alfalfa-grass mixtures is recommended. The goal here is to bring together the positive silaging properties of grass and the high feed value of legumes. Grasses should account for a minimum of 50% share in such mixtures. Furthermore, increasing the share of grasses leads to a clear improvement in suitability for silaging compared to pure stands. The high sugar and low protein content of grasses, combined with a reduction in the buffer capacity, help to ensure that legume-grass mixtures reach the required degree of suitability for silaging. Good results along these lines have been achieved with mixtures of red clover with Italian or perennial ryegrass and mixtures of alfalfa with cocksfoot or false oat-grass.

With respect to the silaging parameters, legume-grass mixtures can be considered to be thoroughly suitable for silaging with an S/BC ratio of 1.8 and an FC of 50.

Smooth exposed silo faces and sufficient feed-out help to prevent faulty fermentation.

5 Grassland management throughout the year

5.1 Harrowing and levelling

Grassland maintenance includes all measures that contribute to improving the plant population. These generally include harrowing, rolling and post-grazing mowing. Grassland maintenance begins in the spring, generally with levelling or harrowing the fields. Today, tine harrows have replaced traditional chain harrows in many applications. Both techniques help to smooth out uneven patches and aerate the grass sward. While chain harrows are better at levelling uneven areas like molehills, tine harrows offer a much more pronounced aeration effect. This stimulates new growth while also helping to induce tillering. Harrowing in this manner is normally not harmful to existing grass roots and thus helps to improve the sward thickness. In matted areas, aggressive harrowing with increased tine penetration is particularly effective at controlling rough-stalked meadow grass while also removing dead, shallow-rooted grasses. Furthermore, harrowing helps to break up livestock manure that has been applied to the field and work it into the sward. This also applies to any mounds of droppings on the pasture surface. Breaking these up helps to reduce the occurrence of rank patches.

Info

Harrowing provides air for reseeding.

Modern combination equipment can offer the advantages of harrows and levellers while also reseeding grasslands.

5.2 Rolling

Due to changing climatic conditions, the importance of rolling has declined considerably in many regions. The practice mostly serves to restore soil contact on humus-rich sites with frost heave. It also forces down protruding stones and smooths out uneven areas in the soil. Additional effects can include the suppression of trampling-sensitive weeds such as cow parsley or hogweed. Soil moisture is an especially important consideration for rolling. The soil cannot be too wet or too dry, since under dry conditions rolling has no effect. When the soil is wet, there is a significant risk of harmful soil compaction occurring or the grass sward becoming washed out.

The frequency of rolling on grasslands has decreased considerably in recent years.

5.3 Reseeding

Reseeding is generally carried out alongside spring harrowing, since harrowing creates favourable conditions for seed germination. A distinction can be made between overseeding and interseeding. For overseeding, it is important for harrowing to create gaps over a large area of the grassland, which will help ensure soil contact for the grass seeds that are sown. It is recommended that this should only be done with competitive varieties of perennial ryegrass at a sowing rate of 5-8 kg/ha. Due to the difficulty in becoming established, overseeding is repeated over several years, or is sometimes even repeated multiple times in a single year.

The use of Coated Seed in these measures can lead to significantly higher germination rates, which can help to increase the effectiveness of reseeding efforts. This is primarily achieved by increasing soil contact through an increased TGW. In addition, the seedling has access to the nutrients it needs immediately upon sowing, which helps to significantly improve the germination process.

Reseeding with a broadcast seeder

Vredo overseeding machine

Coated Seed

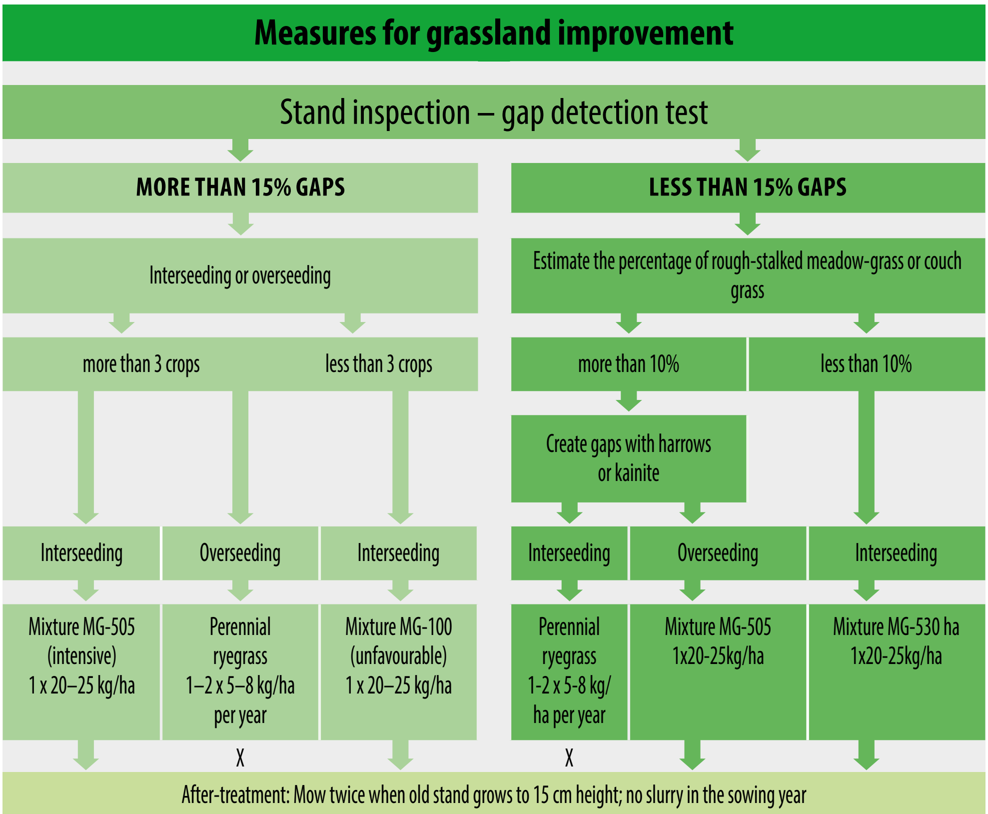
The Coated Seed consists of seeds coated with essential substances that promote germination. The coating is made up of several components, including calcium carbonate for pH regulation. The advantages of Coated Seed for reseeding are clear:

- *Easy sowing and uniform seed distribution*
- *Sowing can be performed with a fertiliser or slug pellet broadcaster*
- *Higher emergence rates due to better soil contact*
- *Excellent development of young plants through an optimal supply of nutrients to the seedling*
- *Seeds remain where they are sown and are not carried away by wind*
- *No feeding damage by birds and rodents*

Interseeding is carried out using specialised equipment such as slit seeders, seed drills or precision seeders. The goal of interseeding is to ensure considerable improvements in soil contact compared to overseeding. Depending on the intensity, this can lead to the destruction of either a small or large portion of the sward, which can interfere considerably with the established stand. However, the resulting field emergence of seeds is generally much higher.
Due to the reduced competition, it is possible to plant other valuable grass species such as Timothy grass, smooth-stalked meadow grass and meadow fescue, in addition to perennial ryegrass. The seeding rate should be between 20 and 25 kg/ha.

If interseeding is possible, it is absolutely essential to ensure the following:

- *Interseeding must be carried out in a short timeframe.*
- *The existing stand should contain a moderate level of gaps (no less than 20%).*
- *Prior control of significant weed populations.*
- *Early cutting of subsequent growth.*
- *Sufficient basic fertiliser is applied, with an initial N application of up to 30 kg N/ha.*
- *Halt to slurry application in the planting year.*
- *The field should be mowed 1-2 times after sowing.*



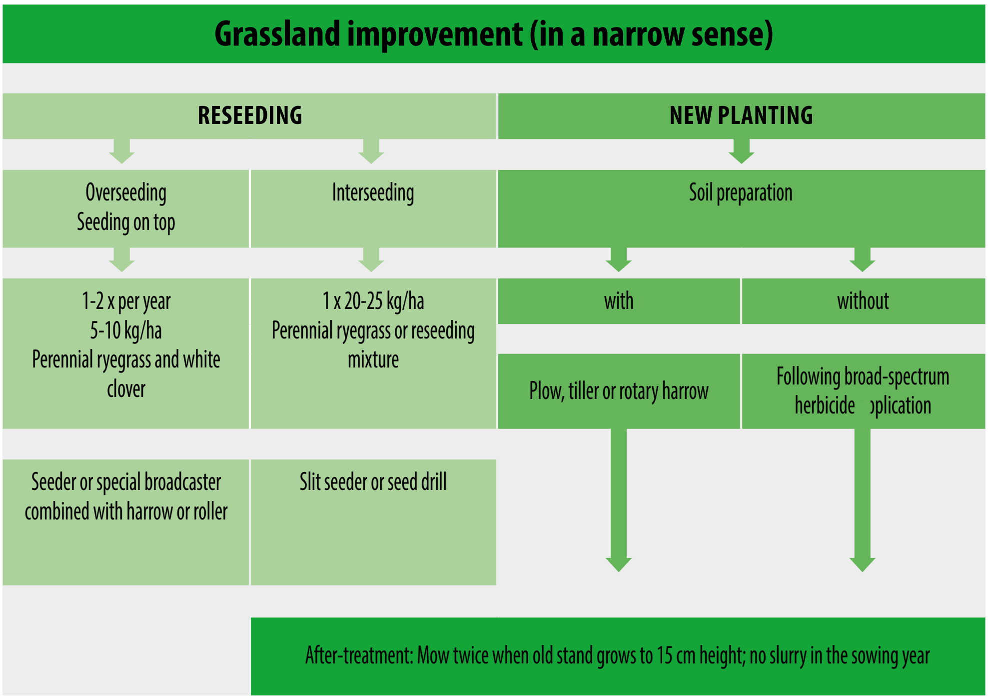
5.4 New planting

Unlike reseeding, which is more common, new grassland planting should only be carried out in certain cases – generally if a stand of plants has been severely damaged or has very low productivity. These situations can be caused by massive weed infestations (> 50% of low-value or harmful grasses like rough-stalked meadow grass) or an extremely damaged sward (wild animal damage). It is clear that new planting results in elevated costs and involves a certain risk. Therefore, appropriate measures must be taken meticulously and in a site-specific manner in order to obtain long-lasting and cost-effective use from the site. In any event, prior discussions should be held with the relevant authorities in order to look into legal and contractual responsibilities. A variety of options exist for new plantings: a distinction needs to be made between soil preparation and broad-spectrum herbicide application.

A combination of a broad-spectrum herbicide followed by soil preparation should be considered in cases of major infestations of weeds that multiplicate via their roots.

Info

New planting can make more sense than reseeding in the event of grasslands with serious damage.



In several federal states, intensive soil preparation is only allowed if an application is approved. Furthermore, the process can involve several significant risks, including severe mineralisation and the extreme tampering with the soil structure. At the same time, the favourable germination conditions after soil preparation can also create an opening for undesirable species such as sorrel.

The sowing date is of vital importance for new plantings, and is generally based on the available soil water content and the expected precipitation levels. In dry sites, late autumn or early spring are the recommended planting times, while areas that see higher precipitation should plant in late summer. On relatively problem-free sites, new planting can take place between spring and late summer.

On more extreme sites, it may be advantageous to protect the new planting against frost using a cover crop or similar intervention. The use of annual ryegrass has shown promise in this regard, particularly varieties that tend to concentrate their yield in the first cut.

An ideal seedbed for grass seeds should be well-distributed with fine texture at the surface. Since grasses require light to germinate, the sowing depth should be no more than 0.5-1.0 cm. The seeding rate should be between 25 and 35 kg/ha, depending on the mixture. Seeding in two criss-crossing paths helps the sward to rapidly cover the ground. Cambridge rollers directly after sowing are recommended on nearly all sites, as they provide an additional boost to soil contact.

In contrast to reseeding, post-sowing maintenance is vitally important for new plantings, contributing significantly to successful emergence. Unfortunately, this stage is all too often left out in practice, which has a negative effect on the resulting stand. The aim is to target emerging weeds through an initial mowing and prevent them from growing further. This should ideally occur once the stand has reached a height of 10-15 cm. Doing so has the positive side effect of encouraging tillering in the grass population, leading to rapid closure of the sward.

The conversion of arable land to grassland is a rare occurrence.

5.5 Post-grazing mowing

When planning out the year's activity, mowing can be a final component of the maintenance programme. It may, however, also be useful to mow between individual grazing periods. The aim is to eliminate undesirable weeds that have not been consumed by the grazing animals in order to prevent them from releasing their seeds. The same applies to fodder remaining after the first grazing period, since mowing can lead to noticeable improvements in the quality of the second-growth forage.

Info

Maintenance cuts should be carried out on fields under high weed pressure.

If the end of a lengthy grazing period is reached or rank patches have formed, the pasture is due for a maintenance cut.

5.6 Avoiding damage from soil compaction

While new plantings are at an especially high risk of damage from soil compaction, the danger is also present on existing stands. Compaction should always be seen as a function of the usage type and the soil water content. Compaction risks mainly arise due to increases in soil water content. The same applies to increased axle loads on machines with small footprints. Special care should be taken when carrying out harvesting operations and applying livestock manure. Excessive grazing densities can also be risky, often leading to point damage around feeding or watering areas.

Using wide tyres with low air pressure can increase the footprint of agricultural machinery and thus markedly decrease the pressure applied to the soil. Grasslands are often at risk due to the effects of groundwater or periodic flooding, especially on alluvial soils or gleysols. Grass roots only intensively penetrate the upper 20 cm of soil, which does help make grasslands highly trample-resistant. However, this also means that when soil compaction occurs, the growth of roots and the soil structure is heavily impacted.

In the worst-case scenario, high-performance grasses are suppressed and other species more adapted to compacted soil prevail. Swards are significantly damaged in these cases, with sizeable decreases in stem density and resilience.

Soil compaction damage can be detected through the presence of indicator species such as broadleaf plantain and annual meadow grass, as well as through lower growth, altered soil structure or persistent surface water that cannot drain away due to the compacted soil. The aim should always be to prevent soil compaction damage in any form. Reseeding in stands with prominent gaps is an important agronomic measure to combat compaction. Especially in marginal sites, soil moisture should be checked before grassland management work is carried out.

Info

Soil compaction has a massive impact on grassland productivity.

Appropriate management practices can help prevent compaction.

5.7 A year in the life of a grassland

January	February	March	April	May	June	
			Field monitoring			
	Slurry application per current fertiliser regulations					
Livestock manure application per current fertiliser regulations						
	Aerate (harrow) sward, level out, roll if necessary					
	Reseeding (main season)			Reseeding		
			New planting (main season)		Reseeding	
				Harvest date		

<table>
<tr><th></th><th>July</th><th>August</th><th>September</th><th>October</th><th>November</th><th>December</th></tr>
<tr><td colspan="3">Field monitoring</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Slurry application per current fertiliser regulations</td><td></td><td></td></tr>
<tr><td colspan="7">Livestock manure application per current fertiliser regulations</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="3">Lime application</td></tr>
<tr><td></td><td></td><td colspan="2">Control rough-stalked meadow grass</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">(off season)</td><td colspan="2">Reseeding (main season)</td><td></td><td></td><td></td></tr>
<tr><td>(off season)</td><td colspan="2">New planting (main season)</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Harvest date</td><td></td><td></td></tr>
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6 Choosing seeds and varieties

6.1 The right mixture for the intended use

Any form of reseeding or new planting represents a drastic impact on the current grassland population. The goal of these interventions is always to add valuable or well-adapted species to the population and to increase the proportion of certain species. This means that the species and, ultimately, the varieties planted have an enormous influence on the final quality of the intervention. Depending on how the grassland is put to use, the grasses introduced in chapter 2 (meadow fescue, Timothy grass, smooth-stalked meadow grass and perennial ryegrass) are recommended for planting with few restrictions. In special circumstances such as extreme site conditions or very intensive/extensive systems, various other species can be planted. The number of suitable species is extremely low, in particular, on sites that will see very intensive use, frequently leading to pure stands of perennial ryegrass. The specific varieties used on such sites then become especially important, since each variety is different in terms of site suitability, persistence, quality, intensity of utilisation, susceptibility to diseases and many other aspects.

In addition to choosing the right variety, the quality of the seeds used in planting also plays a significant role. Two fundamental aspects, namely germination capacity and the presence of seeds from undesirable species (e.g. sorrel), are key practical considerations. The German Seed Marketing Act therefore sets minimum requirements for seed producers. The table on the right, however, demonstrates why it makes more sense to use top-rated mixtures with quality that measurably exceeds the legal standard. For example, if we take a cheap seeding mix that conks out after just four years, the cost per year is €85/ha. With a top-rated mixture that lasts for eight years, the cost is just €48/ha/year. The same can be seen in reseeding mixtures.

Seed quality and associated costs					
		Low	Medium	High	Very high
Seed price	**€/kg**	3.10	3.50	4.10	4.60
Seed price	**€/ha**	93.00	105.00	123.00	138.00
Planting costs	**€/ha**	248.94	248.94	248.94	248.94
Total	**€/ha**	345.04	357.44	376.04	391.54
Duration	**Years**	4	5	6	8
Proportional cost	**€/ha/year**	85.00	71.00	62.00	48.00

Very high-quality seeds result in the lowest per-year costs

Perennial ryegrass is one of the most important components of seed mixtures.

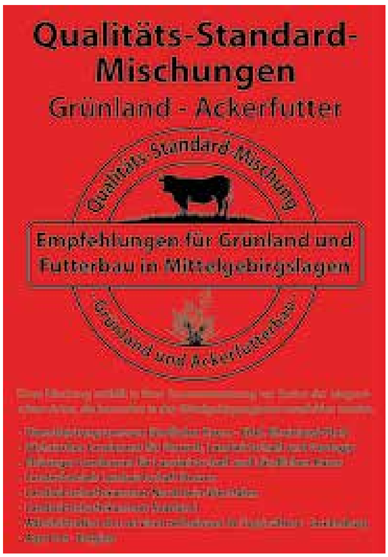
6.2 Regional and variety recommendations

The effects of poor grassland are felt in the barn and in the wallet. High-performance grasslands will grow in both favourable and unfavourable locations only if the sward contains exclusively high-quality grasses and clover species.

This can only be achieved with grass and clover varieties that are adapted to regional conditions. Sub-quality swards can never meet the quality requirements of high-performance dairy cattle feed – with consequences in the barn and in your wallet. Grasslands must be productive: in addition to a high yield for winter fodder production and grazing, they must offer perennial growth and form a dense sward.

To this end, the species and varieties contained in the mixtures must be adapted to the special climatic conditions of the respective region, both for reseeding and for new planting. Germany is divided into five advisory regions with special consideration for the geographical and climatic conditions of each. These regions can be found on the map.

The varieties used in the quality seed mixtures are subject to numerous tests. The varieties' suitability for the conditions of the respective areas are examined in planting trials, while the mixtures are checked by the Chamber of Agriculture. Here, samples are taken from the mixtures available on the market and examined for species composition and germination capacity. The perennial ryegrass varieties that are planted in the low mountain regions are also checked for varietal identity. This ensures that only the recommended varieties are included in the mixtures. Different approaches are used when examining seeds intended for the low mountain and lowland regions. The most important values – for which the recommended varieties must meet a minimum threshold – are high resistance to disease, persistence, total yield, fodder quality and steady, reliable yields. In seeds intended for the low mountain regions, great importance is attached to winter-hardiness as well. In lowland areas, suitability for cultivation in locations with boggy soil is also tested. However, it must also be ascertained whether the recommended variety can withstand the specific features of the local climate.



Regional recommendations Germany

- NWL
- RHT
- Saxony-Anhalt, Brandenburg, Mecklenburg-Western Pomerania
- Baden-Württemberg
- Bavaria

The following points should be taken into consideration by individual operators when choosing mixtures:

Info

- Should you intensify a permanent grassland, or convert the land to field forage production?
- Is the presence of legumes desired in order to reduce fertiliser costs?
- What grassland mixture offers the highest mass yields? The highest energy yields?
- What mixtures are most persistent?
- Are any mixtures better suited to the changing climate conditions?
- What maturity groups should be used in order to fit with the site characteristics?

Permanent grasslands or field forage systems

Due to their different species compositions, permanent grasslands and field forage systems do not reach their optimal harvest date simultaneously. Permanent grasslands are generally cut 3-4 times per year, while field forage systems are cut 4-5 times at a minimum. Due to the rapid growth of field forage crops, their first growth is ready to be cut 14 days earlier than permanent grasslands. Exceptions to this rule are very early-maturing species like cocksfoot and meadow foxtail. The subsequent regrowth of field forage is also considerably faster.

Legumes: yes, no, how much?

For economic reasons, there is increasing interest in the ability of the nodule bacteria on leguminous plants to fix atmospheric nitrogen and make it available to the entire plant population. As a rule, every additional percentage point of clover in the grassland sward provides around 5 kg of nitrogen per hectare per year. In financial terms, this means that a stand with 20% clover will see fertiliser savings of 100 kg N per hectare, or fertiliser costs of €100 per ha.

Nodules (pink on the inside) make atmospheric nitrogen available to plants

Yield can be optimised by choosing the right mixture

Optimal field composition for intensive utilisation with high yield and quality

60-80% valuable grasses

Advantages: Yield, quality, sward density, persistence

10-20% legumes

Advantages: N fixation, mineral content, flexible harvest period, inclusion in forage

Drawbacks: Low crude fibre content, crop losses, poor suitability for silage

10-20% herbs

Advantages: Mineral content, secondary compounds, biodiversity

Drawbacks: Low yield, drying properties, crumbling losses

What are maturity groups in perennial ryegrass?

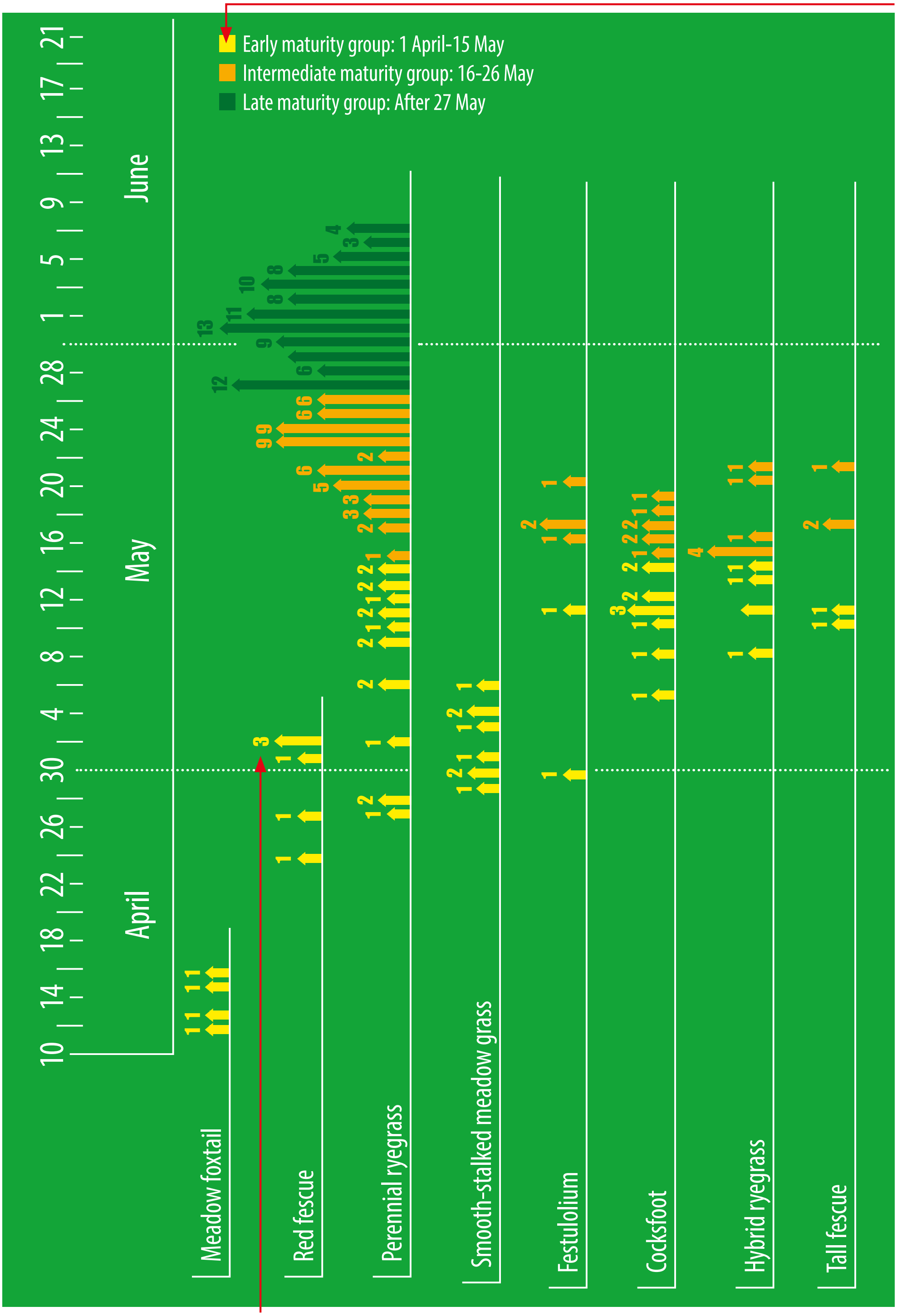
The different maturity groups play an especially important role in perennial ryegrass. Three groups (early, intermediate and late) can be distinguished, with each group further divided into three sub-groups. There is an interval of around six weeks between the dates on which spikes emerge in early and late varieties of perennial ryegrass.

When determining the right mixture for a given operation, it is essential to find a combination of distinct maturity groups in order to optimise yield, quality and risk distribution. For example, given an intermediate date for the first grazing or cutting (e.g. mid-May), spikes will have emerged among the plants in the early maturity group; they will just be starting to emerge in the intermediate group, while the late group will still be in the shoot stage, but will have reached the highest energy concentrations. Changes in the climate, along with an increasing frequency of extreme weather and dry spells, highlight the importance of maturity groups. In particular, the impacts of spring droughts have increased.

In order to use up the moisture accumulated over winter, it is vital to consider the yield advantages that early varieties offer over later ones. Early varieties produce average dry matter yields in the first growth (mid-May) that are 25% higher than late varieties. Due to their advanced reproductive development, they also provide more structured crude fibre for silage.

Cultivation trials serve to determine the maturity group

In Germany, there are currently 16 approved varieties of perennial ryegrass in the early maturity group. These are further divided into three sub-groups: very early, very early to early, and early.



There are currently three red fescue varieties whose panicles emerge at this point.

Spike and panicle emergence and duration in fodder grasses after 1 April

6.3 High-quality standard grassland mixtures

A wide array of varieties of several grass species are available on the German and European market. However, not all varieties are suitable for all climatic zones, even if they are approved for distribution or sale in a given region. Regional authorities in each federal state therefore conduct agricultural trials, on the basis of which they recommend special varieties of individual grass species which have been shown to perform particularly well under local conditions.

High-quality standard grassland mixtures are divided into those meant for meadows and ones for permanent pastures and/or hay pastures. It should be noted that, as a general rule, the share of perennial ryegrass generally increases with the intended intensity of usage. No perennial ryegrass is used in the standard mixtures for meadows. Instead, they tend to feature meadow fescue more heavily. On particular sites (increased drought risk or very wet), special grasses are included in the mixture (e.g. cocksfoot or meadow foxtail) in order to meet the site requirements. In meadow mixtures, grasses are supplemented with leguminous species such as white clover, red clover, alfalfa or special species (alsike clover). White clover is sometimes used in pasture mixtures. For reseeding of all kinds, only pure perennial ryegrass mixtures are used, though these can be supplemented with white clover if desired. All other grasses are unable to deal with the high competition to which reseeded species are subjected.

Permanent pastures and hay pastures

G I: For all sites with low frequency of utilisation (3x per year)
For cutting and grazing

G II: For all sites with a frequency of utilisation of 3-5x per year
For grazing and/or cutting

G II o: Like G II; specially designed for fields where herbicide application is expected during the establishment phase

G III: For all sites with very high frequency of utilisation, pastures, short-grass grazing systems

G IV: For drought-prone sites and sites with dry summers

G V: For reseeding in swards with gaps and for overseeding to stabilise swards

GV mK: Similar to G V, contains white clover

G VI: Primarily for use as pasture (young cattle pastures)

Meadows

G VII: For sites with wet or periodically wet conditions, including temporarily flooded sites

G VIII: For wet sites or sites with ample water availability, as well as for uplands

G IX: For moist and warmer sites

G X: For dry sites

Species	Permanent pastures and hay pastures								Meadows			
	G I	G II	G II o	G III	G IV	G V	GV mK	G VI	G VII	G VIII	G IX	G X
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Perennial ryegrass												
Early	1	4	4	6		5	4					
Intermediate	1	5	6	6		5	4					
Late	1	5	6	8	8	10	10	2				
Meadow fescue	14	6	6						13	15	10	5
Timothy grass	5	5	5	5	5				5	5	3	1
Smooth-stalked meadow grass	3	3	3	3	3			4	5	3	5	5
Red fescue	3							12		3	6	6
Cocksfoot					12							4
White clover	2	2		2	2		2	2	2	2		
Tall oatgrass											3	
Meadow foxtail									2			
Creeping bentgrass									1			
Red clover										2	1	
Alsike clover									2			
Lucerne (alfalfa)												1
Bird's-foot trefoil											2	2
Black medick												1
Seeding rate in kg/ha	**30**	**30**	**30**	**30**	**30**	**20**	**20**	**20**	**30**	**30**	**30**	**25**

QSM summary for permanent grasslands in NRW

7 Fertiliser application

7.1 Soil analysis: The starting point for all actions

In general terms, an optimal supply of soil nutrients has a significant influence on the yield levels of agricultural crops. This is true for both food crops and grasslands, highlighting the importance of soil nutrients for the economic success of the production system.

The nutrient requirements of grassland soils, furthermore, are often considerably underestimated. Optimal forage yields can only be obtained from high-grade plant populations, which require targeted and efficient applications of plant nutrients that are tailored to site-specific characteristics at varying yield levels. As such, it is important to be aware of important parameters such as nutrient availability in the soil, nutrient removals by fodder, and nutrient additions from livestock manure.

Soil analyses are a key first step for obtaining reliable information about the management-relevant and site-specific conditions. Even in grasslands, they should be carried out at regular intervals and analysed thoroughly. The results of these analyses can be used to optimise fertiliser applications and make them more cost-effective. In addition, soil analyses of essential nutrients serve to fulfil basic statutory requirements, including those of the German Fertiliser Regulation and Cross Compliance.

Basic analyses, versions of which may be offered by the relevant local authority (NRW: LUFA), provide data on parameters including plant-available phosphorus, potassium and magnesium, as well as soil pH. Furthermore, there are a variety of different services which can provide precise information on a given field's nutrient requirements based on removal, addition and leaching of nutrients along with a host of additional factors.

Info

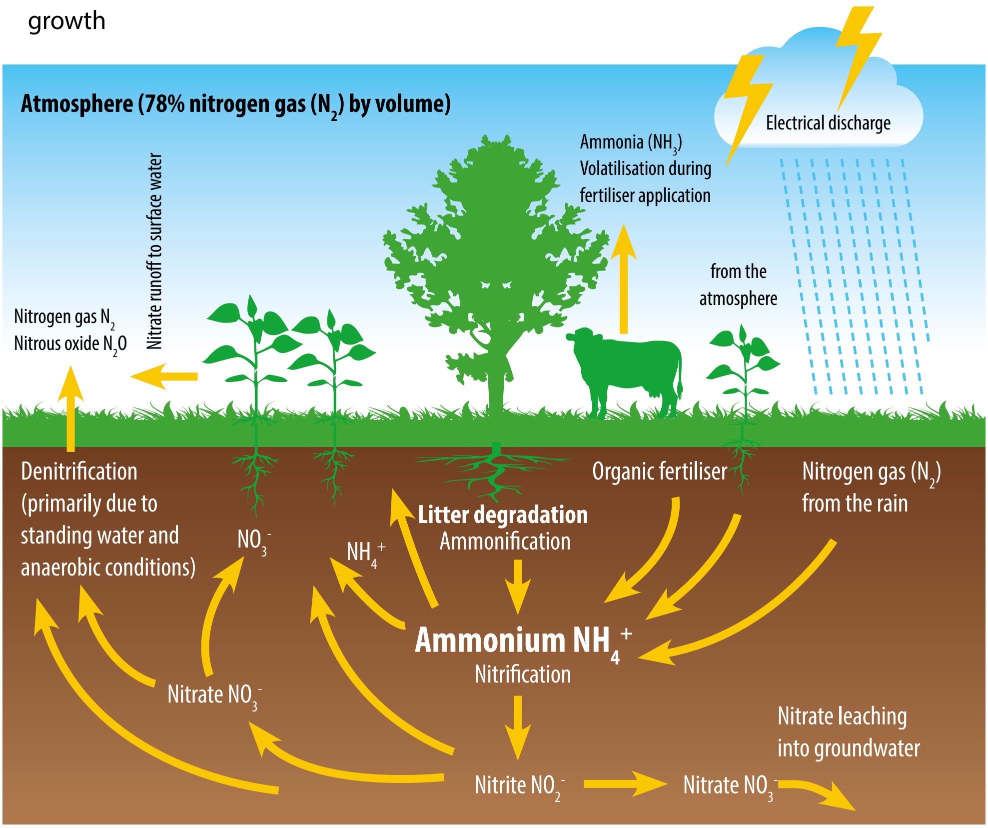
Soil analyses are essential for targeted planning of fertiliser application

7.2 Nitrogen

Nitrogen (N) is the most important plant nutrient, since it functions as the engine of plant growth. Nitrogen is present in a variety of forms in the ground, depending on fertiliser application and the soil environment. Plants are able to access the sources of nitrogen to varying degrees. Plants can absorb both ammonium and nitrate equally well, with nitrate being converted back into ammonium inside the plant. Nitrogen plays a variety of functions within the plant:

- Important building block of proteins
- A component of enzymes and chlorophyll
- Supports vitamin formation
- Growth rate ➟ The engine of plant growth

Due to plant physiology, nitrogen is mainly needed in the plants' meristem, which is where growth occurs. Meristems are found in the tips of the roots and shoots, among other areas, meaning that nitrogen is transported in both directions within the plant. Plants can only access nitrogen from the soil, primarily as nitrates (NO_3^-) and, to a lesser extent, as ammonium (NH_4^+).



The nitrogen cycle in a grassland

The roots of pasture grasses are primarily located in the upper 10 cm of soil, though rooting depths of 20 cm or greater are possible depending on the particular system. What this means for the nitrogen supply of the plants is that nitrogen must essentially move towards the parts of the roots that can absorb it. The nitrogen requirements are generally based on the yield of the corresponding grassland area. It should be noted that both yield and nutrient needs rise in tandem with greater intensification. The annexes of the current German Fertiliser Regulation (DVO) provide clear instructions on the specific nutrient requirements that are to be set for different grassland populations. For example, the nitrogen requirements of a three-cut system are set at 190 kg N/ha and at 310 kg N/ha for a five-cut system. This demonstrates that intensive grasslands are able to both absorb and make use of an enormous amount of nitrogen.

Nitrogen requirement for grasslands under new fertilizer regulation (DVO)	Yield level (net)	Crude protein content (% CP/ 6.25 = kg N/dt dry matter (DM))	Nitrogen requirement
	In dt DM/ha	In CP as % of DM	In kg N/ha
Temporary/permanent grassland			
1-cut	40	8.6	55
2-cut	55	11.4	100
3-cut	80	15.0	190
4-cut	90	17.0	245
5 cut	110	17.5	310
6-cut	120	18.2	350
Pasture/hay pasture			
Intensive pasture	90	18.0	130
Hay pasture, 60% pasture	94	17.6	190
Hay pasture, 20% pasture	98	17.2	245

Given an expected yield of 110 dt/ha in a five-cut system, the nitrogen requirement should be set at 310 kg per year

In addition to nitrogen requirements, additional factors such as recovery from soil reserves play a significant role. With increasing amounts of soil organic matter (humus), minimum reductions in nitrogen requirements between 10 and 50 kg N/ha can be applied. On boggy sites, this reduction can be up to 80 kg N/ha. The share of legumes in the stand should also be considered when calculating fertiliser requirements. When legumes comprise 5-10% of the stand, fertiliser application can be reduced by 20 kg N/ha. In pure stands of leguminous plants, the reduction in the fertiliser application is roughly equal to the entire nitrogen requirement of the plants, meaning that applying fertiliser would be redundant.

Deductions based on nitrogen recovery from soil reserves

	Minimum deductions in kg N/ha
Temporary/permanent grassland	
Temporary or permanent grassland soils with very low to high humus (less than 8% soil organic matter)	10
Temporary or permanent grassland soils with high to very high humus (8-15% soil organic matter)	30
Peaty temporary or permanent grassland soils (15-30% soil organic matter)	50
Swamp soil (30% or more soil organic matter)	
Moor	50
Fen	80
Multiple-cut field forage production	
Field grass without legumes	0

Deductions based on nitrogen recovery from nitrogen fixation by legumes

	Minimum deductions in kg N/ha
Legumes in temporary/permanent grasslands	
Legume share of yield 5-10%	20
Legume share of yield > 10-20%	40
Legume share of yield > 20%	60
Legumes in multiple-cut field forage production	
Clover/alfalfa-grass mixture per 10% increment in the legume share of yield	30
Pure stands of red clover/alfalfa	360

Legumes like the white clover variety BOMBUS can make a significant contribution to nitrogen supply

7.2.1 Types of organic fertiliser

The most commonly used organic fertiliser in Germany is cattle slurry. It is a particularly valuable component due to the high concentration and wide array of nutrients it provides. The nutrients contained in livestock manure can vary widely depending on their moisture content and animal feed. This highlights the importance of being aware of the composition of slurry. Carrying out an analysis once or twice per year is therefore essential. The technique used to spread the manure is just as important as its composition for ensuring that the inexpensive manure is used efficiently. Most slurry is applied to fields using a wide broadcasting technique. This technique is, however, increasingly being replaced by a system that lies closer to the ground and/or by working the manure directly into the soil. These new techniques ensure that slurry is distributed precisely and reduce ammonia losses due to volatilisation while the manure is being spread.

Livestock manure	DM in %	Nitrogen		P_2O_5	K_2O	MgO	CaO
		Total	NH_4-N				
Solid manure (rotten) pert							
Cow manure	25	5	0.4	3	7	1.5	3.5
Pig manure	23	6	0.5	4	3	2	4
Sheep manure	25	8	0.6	3	7	2	3.5
Horse manure	25	6.5	0.5	3	6	1	3
Chicken manure	45	28	7.8	24	23	6	22
Turkey manure	45	18	5	20	16	5	18
Poultry manure per t							
Fresh chicken droppings	23	13	6	8	7	2	21
Dry chicken droppings	45	24	10	17	14	5	42
Liquid manure per m³							
Liquid cow manure	2	3	2.7	0	8	0	0
Liquid pig manure	2	4	3.6	1	3	0	0
Slurry per m³							
Thin cattle slurry	5	2.9	1.7	1.2	3.1	0.6	1.2
Normal cattle slurry	7	3.5	2.0	1.5	3.9	0.8	1.6
Thick cattle slurry	9	4.2	2.3	1.8	4.6	1.0	2.0
Thin pig slurry	1.5	2.5	2.1	0.8	1.8	0.3	0.8
Normal swine slurry	3	3.6	2.8	1.7	2.4	0.6	1.5
Thick swine slurry	4.5	4.4	3.3	2.5	3.0	0.9	2.3
Chicken slurry	14	9.2	6.5	7.0	5.0	1.8	15
Biogas substrate residue per m³							
BSR with 4-6% DM	5.2	4.0	2.3	1.5	4.1	0.6	
BSR with 6-8% DM	7.2	5.1	2.9	2.1	5.4	0.8	

Average nutrient content of different livestock manures in kg/t or m³ wet mass

7.2.2 Types of mineral fertiliser

Nitrogen is present in the soil in an organically bound form as humus as well as in an inorganic or mineral form (ammonium and nitrate). Due to the legal provisions of the German Fertiliser Regulation, organic fertiliser alone is not sufficient to cover the nutrient requirements of plants in intensive systems. In these systems, farmers have the option of supplementing organic fertiliser applications with mineral fertilisers. The advantage of mineral fertilisers lies in the sheer number of products on offer. These allow producers to choose a combination of the necessary basic nutrients that can be adapted to the assessed needs of the plant population. The different methods of action offered by mineral fertilisers represent an additional advantage. The fertilisers on offer include ones with extremely rapid action as well as slow-release fertilisers.

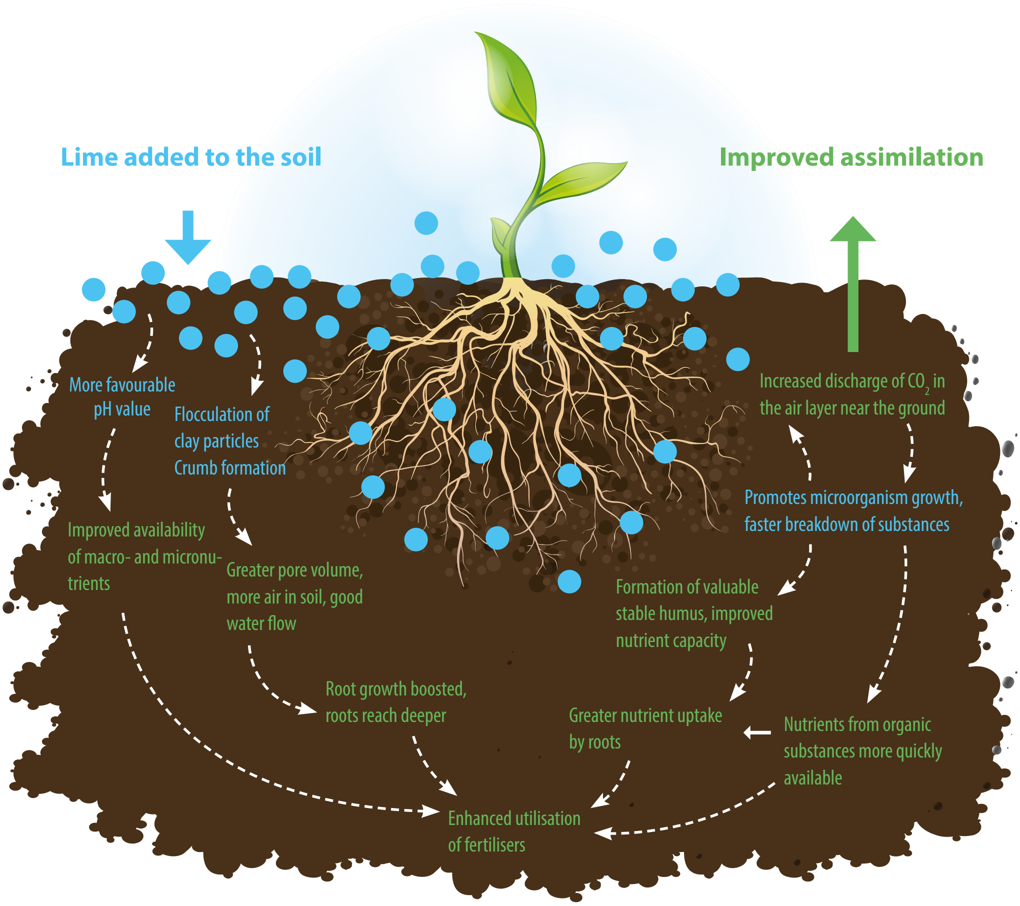
A variety of transformational processes are constantly acting on the different forms of nitrogen in the soil. Crucially, not every form of nitrogen is equally beneficial for plant life. Nitrates are present in the soil under natural conditions and are also a component of a variety of mineral fertilisers. Unlike ammonium, nitrate dissolves in water and can therefore move easily. Nitrate fertilisers can therefore quickly reach the groundwater and enter plant roots. Their activity is not influenced by weather conditions.

In contrast, ammonium is fixed by clay minerals or humus and is only available to directly adjacent plant roots. In addition to direct uptake by plants, ammonium is transformed by the nitrification process, in which bacteria convert it to nitrate, which is more readily available to plants.

Fertiliser spreader from Amazone® for applying mineral fertiliser

7.3 Lime

As a fertiliser, liming is primarily equivalent to soil fertilisation and is the most effective manner of altering soil pH. In addition, herb-rich grassland populations in particular can remove up to 150 kg CaO/ha from the soil. This removal of CaO, combined with the acidic effects of nitrogen fertilisers and slightly acidic precipitation, result in significant amounts of lime being removed from the soil every year. This results in a decrease in soil pH. As with other nutrients, LUFA provides information on soil lime content and pH value, summarised as content classes. Measures should be taken to achieve content class C, since soils in this class have optimal supply of minerals, the yield potential is ensured, and plants are fully supplied with nutrients.



Direct effects of lime
Indirect effects of lime

Factors that decrease available lime: Leaching losses, harvest losses, acid precipitation, lime-degrading organic and mineral fertilisers, soil respiration, acidifying action by microorganisms, oxidation of biologically bound oxygen

The pH value has three main functions in the soil in terms of creating long-lasting soil fertility and providing plants with optimal quantities of the nutrients they need to grow:

1. Chemical effects: Nutrients are more or less readily available to plants depending on the pH value. For example, nutrients like phosphorus are very readily available to plants in a weak acidic to neutral range (pH 6-7). Trace elements such as manganese are frequently unavailable to plants on soils where good amounts of lime have been applied.

2. Physical effects: Applying lime increases the stability of clay minerals and prevents them from being relocated into the subsoil. At the same time, lime promotes the creation of clay-humus complexes, which contribute to increased aggregate stability. This allows the soil to withstand mechanical stresses more effectively, while decreasing its vulnerability to erosion and silting. It also increases the soil's air, water and heat balance.

3. Biological effects: A pH level that is suitable for the soil increases its biological activity. This leads to improved decomposition processes and the intensified conversion of substances by a wide array of soil organisms. Improved mineralisation also helps to provide plants with nitrogen.
Before applying lime, the soil's levels of lime should be determined with a soil sample. The current level is not the only consideration when deciding on the necessary amount: this also depends heavily on the soil type and humus content. The lower a soil's buffer capacity, the less lime a single application should contain. This helps avoid overly rapid changes in soil pH as well as the potential negative effects this may cause.

Soil type	Target pH value and maintenance liming in kg CaO/ha depending on humus content in %					Maximum lime application per year in kg CaO/ha
		≤ 8%	8.1-15 %	15.1-30 %	> 30%	
S	pH CaO	5.0 500	4.8 400	4.5 300	4.3 0	1000
LS, SSi	pH CaO	5.4 600	5.2 500	5.0 300		1000
VSL, LSi	pH CaO	5.7 700	5.4 600	5.1 400		1500
SL, SiL, L	pH CaO	5.9 800	5.6 700	5.3 500		1500
SiCL, CL, C	pH CaO	6.1 900	5.8 800	5.5 600		2000

7.4 Phosphorus

Grasslands are frequently supplied with phosphorus using conventional livestock manure. Grassland sites are no different from comparable crop fields in terms of the optimal level of soil phosphorus supply. Since phosphorus plays an important role in a plant's energy balance, an appropriate supply should be ensured.

Soil type	Phosphorus content in mg/100g soil				
	A Very low	B	C Target value	D	E Very high
S, LS, SSi, VSL, LSi, SL, SiL, L	≤ 3	4-9	10-18	19-32	≥ 33
SiCL, CL, C	≤ 5	6-13	14-24	25-38	≥ 39

Numerous studies have shown that when the target phosphorus content is exceeded, there are no additional positive effects in terms of yield or quality. Phosphorus content under the target value for a short period of time has also been shown to have no immediate negative consequences. Therefore, the recommendation is to carry out maintenance fertilisation as appropriate based on the amounts removed from the site.

Phosphate mining in Morocco

Current discussions on the oversupply of nutrients and the damage caused to waterways by phosphorus make it clear that producers should strive to use phosphates as efficiently as possible. Therefore, care should be taken to keep the current supply available through appropriate crop management practices and to tap into fixed phosphorus reserves.

These management practices include maintaining an optimal soil pH and good levels of organic fertilisation, as well as avoiding damage from soil compaction in the root zone. Since plant roots only absorb phosphorus from their direct surroundings, it is important to promote healthy root development.

7.5 Potassium

Potassium is a highly mobile nutrient in both plants and the soil. For grassland plants, potassium plays a particularly important role in the water supply within the plant. Due to its role in controlling stomata, potassium can be a life-saving nutrient during periods of water stress. It also influences tissue stability, helping to prevent lodging. This makes fungal infections more difficult while also increasing the field's ease of harvesting and ensuring high fodder quality. A sufficient supply of potassium also protects the plant population from excessive frost damage. Potassium also influences two other nutrients: nitrogen and magnesium. If a grassland is oversupplied with potassium, this makes magnesium supply more difficult, since the nutrients have antagonistic effects on one another. This can also have an effect on animals' ability to obtain sufficient magnesium. The relationship between nitrogen and potassium is somewhat different: good potassium supply increases plant nitrogen uptake.

Soil type	**Potassium content in mg/100g soil**				
	A Very low	B	C Target value	D	E Very high
S	≤ 2	3-5	6-12	13-19	≥ 20
LS, SSi, VSL, LSi, SL, SiL, L	≤ 3	4-9	10-18	19-32	≥ 33
SiCL, CL, C	≤ 5	6-13	14-24	25-38	≥ 39

Finally, it should be noted that pastures need less potassium fertiliser than meadows. On pastures, much of the required potassium is returned to the soil in dung and urine during grazing periods.

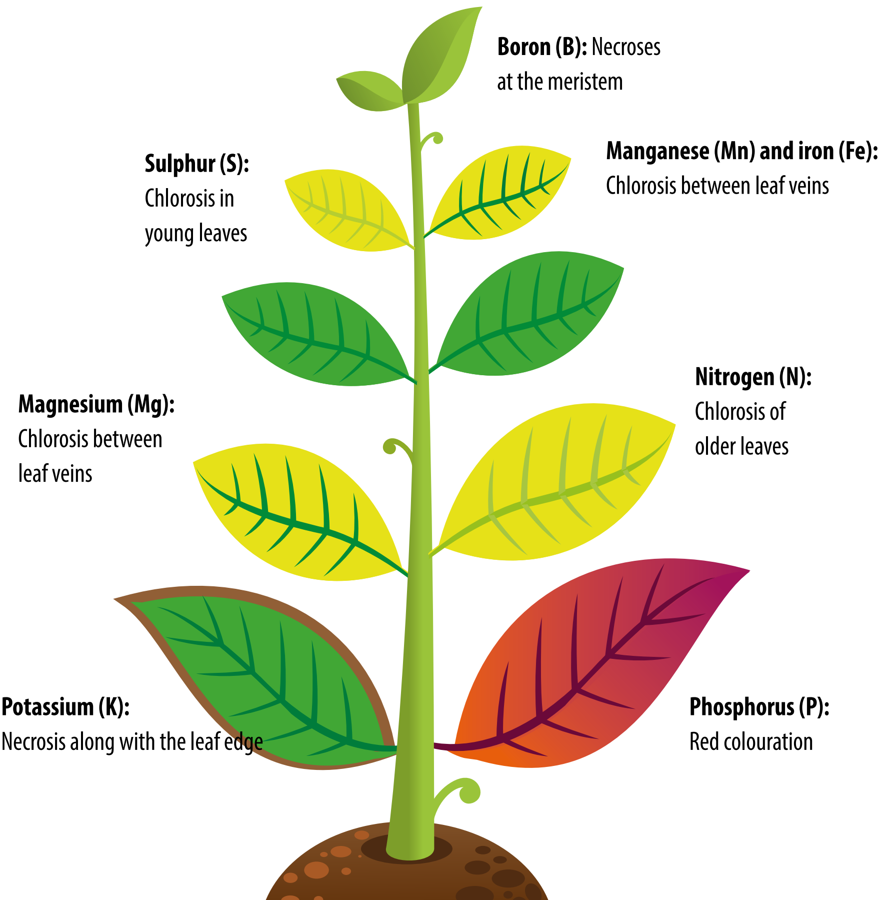
This return of soil potassium is practically non-existent on meadows, since the entire plant growth is taken away, along with the potassium it contains. Potassium that is removed in this manner must be replaced through appropriate fertiliser application.

Potassium salt stockpile in northern Germany

7.6 Magnesium

Magnesium, quite literally, gives grasslands their colour. It is a central component of the green substance that gives leaves their colour, chlorophyll. Furthermore, it also plays a role in storing reserves of fats and carbohydrates. Magnesium also makes it possible to activate enzymes and transfer energy within the plant.

Soil type	Magnesium content in mg/100g soil				
	A Very low	B	C Target value	D	E Very high
All	≤ 3	4-7	8-12	13-18	≥ 19



Symptoms of nutrient deficiencies in plants

Weather conditions must be taken account when administering slurry

The application of solid manure is especially effective in supplying many important nutrients (e.g. magnesium) while also helping to form humus.

7.7 Sulphur

Sulphur is an essential plant nutrient. It is a building block of sulphur-containing amino acids like methionine and cysteine, meaning that it plays a role in plants' protein synthesis. Production of certain amino acids is limited under conditions of sulphur deficiency, which negatively affects nitrogen utilisation. This results in lower protein content as well as increasing the N/S ratio within the plant. The N/S ratio describes the interaction between nitrogen and sulphur. According to the literature, it should be around 10:1 to 15:1. Increasing the N/S ratio can lead to the nitrates taken up by the plant going unused and accumulating. Sulphur deficiency expresses itself, like nitrogen deficiency, in lighter leaf colouration and compressed plant growth. One striking feature of it is that young leaves are the first to show symptoms. Until the late 1980s, sulphur requirements were largely met by inputs from the air and precipitation.

Since then, this input has been reduced from over 50 kg S/ha to around 10 kg S/ha per year, which has led to sulphur deficiencies on many sites. Currently, however, no nationwide sulphur shortage can be said to exist. In field tests, around one-fourth of fields analysed – generally ones with high-intensity utilisation – exhibited a lack of sulphur (Source: Rutzmoeser and Rühlicke, 2000). Yield increases of about 1,000 kg/ha/year can be obtained on these fields with additions of sulphur. Fertiliser applications can take the form of elemental sulphur or sulphate. The former must be transformed through microbial processes, and thus only becomes plant-available quite slowly. It is somewhat suitable as a rectifying fertiliser.

Info

Sulphur deficiencies generally arise after a few years, but are likely to increase in the coming years.

Sulphate is immediately plant-available, but is easily moved in the soil, placing it at a high risk of leaching.

Sulphur deficiencies are likely on the following sites	Deficiencies generally do not occur on the following sites
Temporary grasslands, new intensive fields, legume-rich/ ryegrass-rich populations	Old grassland populations with intermediate intensity of utilisation
First and second growth	Used primarily as pastures
High fertiliser usage (> 250 kg N/ha)	Regular S fertilisation
Systems with predominantly mineral fertiliser use	Humus-rich sites
N/S ratio > 15:1	N/S ratio < 12:1

Characteristics of sites that tend to exhibit sulphur deficiencies and those that do not

Several sulphur fertilisers are available using combinations with nitrogen (CAN, ASN), though the nitrogen they contain generally limits their usefulness in stands with legumes. Little information is available on recommended fertilisation practices, which tend to suggest 30-40 kg S/ha in the form of elemental sulphur. Sulphate and liquid sulphur fertilisers can also be applied at later dates. This is recommended between the early growth stages and the end of vertical growth.

Various mineral fertilisers contain different levels of sulphur

Sulphur factory with stockpile

8 Crop protection

Grassland productivity is extremely important economically. It can, however, be considerably reduced due to major weed infestations, which can result in long-lasting detrimental effects on fodder quality. The impact of weeds can also rise significantly due to decreased utilisation intensity combined with poor fertiliser management. Finally, the presence of undesirable plant species can also be the result of insufficient maintenance or improper utilisation. Grassland maintenance practices are especially important in order to protect them from weed infestations as effectively as possible. These include mechanical weed control measures, treatment of individual plants, field-level applications of appropriate herbicides and measures to control animal pests.

Improving grasslands with mechanical interventions

Early cuts, accompanied by intensive grazing by livestock, can enhance tillering by short grasses and increase the sward density of the grassland population. Uneven areas can be levelled out using chain harrows or rollers, practices which are discussed in further detail in Chapter 5. These measures also prevent the undesirable contamination of fodder and excessive raw ash content, which significantly increases water quality. The aeration of the grass sward using tine harrows can loosen matted swards. Mowing fields after grazing can be an effective way of preventing weeds from releasing their seeds and spreading. Furthermore, doing so helps to boost sward regrowth; a maintenance cut before the beginning of winter can help prevent plants from being winterkilled.

This field is affected by an infestation of sorrel

8.1 Individual plant control

Grassland weeds are undesirable due to their toxic properties (e.g. marsh horsetail, meadow buttercup and autumn crocus) and the harm they cause to the grass sward (sorrel and thistle species). Furthermore, weeds not only compete with grasses for growing space, but also for nutrient reserves, which is why they are considered nutrient thieves. Rosette plants such as sorrels cannot be controlled via grazing or cutting, making them particularly stubborn and disruptive weeds. Both feed uptake and yield are considerably reduced when weeds are present in large numbers, since they can cause higher harvest losses due to crumbling or make it impossible to gather the plant growth during mowing.

Various sorrel species can be commonly found on meadows and pastures with excess nutrients. However, some sorrel species can also be present in populations on nutrient-poor soils with an uneven nutrient supply. As such, fertiliser application plays a key role. Partial or insufficient fertiliser application, as well as stands with too many gaps, provide excellent habitat for all species of sorrel and can boost their growth considerably. The control threshold is reached when the infestation reaches 0.5-1 plants/m^2. Balanced fertiliser application and a uniform nutrient balance can reduce infestations significantly. Increasing the intensity of utilisation, mowing after grazing, and avoiding gaps in the grass sward have all proven to be effective measures. A variety of herbicides have proven to be effective at controlling individual plant species. The timing of treatment is a deciding factor in its effectiveness as a control mechanism. It is recommended to carry out treatment during the growth period while plants are young, or else in autumn. This is because plants store their photosynthetic assimilates from their leaves in their roots during these periods, transporting the substances into their root mass.

In addition, mechanical control of individual plants is possible using a hoe or weed puller. This direct approach seeks to minimise the infestation in its early stages and is especially useful in organic operations. Once it is cut out, the entire plant is dug up and removed by hand with as much of the root mass as possible. Uprooting sorrel plants is a very effective control measure, though it is extremely time-consuming. One alternative is to control individual plants with a hot water pressure washer with a rotary nozzle.

Mechanical control of sorrel using a weed puller

8.2 Field application

Weeds can be controlled over entire fields using a weed wiper, a machine that wipes herbicide onto plant surfaces, or a similar machine. Field treatment with classic crop protection sprayers are also an option. Spraying can, for example, be used to spread growth promoters that can prevent the tuft-like emergence of sorrel species, nettles and thistles. The application rates and the recommended waiting periods should always be taken into account when carrying out these different procedures. In cases of extremely high weed pressure, field-level treatment can be carried out with a broad-spectrum herbicide followed by partial or full new plantings. This, however, must always be a last resort. In addition to chemical treatment of the field, mechanical suppression is also an option.

Undesirable species often emerge when the optimal conditions have been created for them to grow. These conditions, however, are usually different from those preferred by desirable grassland species. Frequent cutting helps against almost all undesirable species. When the growth has a particularly low feed value due to the predominance of nettles or sorrel, it is recommended to mow and remove the growth rather than mulching it. This is especially effective at removing sorrel seeds from the field.

An additional measure that does not involve applying herbicides is fertilising with calcium cyanamide. This is especially helpful against dandelions. Controlling undesired grasses in the stand is somewhat more difficult. Depending on the species encountered, the most sensible approach is often to change the maintenance and management practices so that they no longer fulfil the undesired plant's requirements. At worst, some parts of the field will need to be killed off and replanted. Rough-stalked meadow grass (Poa trivialis) is a special case: it emerges throughout the field, especially in wet years. Controlling this species mechanically is relatively straightforward, since the shallow-rooted grass can be combed out with aggressive tine harrowing. Alternatively, intensive grazing with ruminants can have the same effect.

Controlling sorrel with a Rotowiper® weed wiper

8.2.1 Approved grassland herbicides

Please note your national regulations!

Pest	Product	Requirement	Delay time	Quantity	Remarks
Sorrel species	Harmony SX		14 days	1.5-10 g/10 L water	
	Ranger, Garlon		14 days	0.1-0.4 L/10 L water	Ma[illegible]
	Simplex	WP681-684	7 days	0.1-0.5 L/[illegible]	[illegible]
	Taipan	NW5, NT108	21 days	[illegible]	[illegible]. 1.8 L/ha/ year
Common nettle	Ranger, Garlon		14 day[illegible]	[illegible]	
Sorrel, creeping thistle	Roundup, Powerflex	NG351	[illegible]	33%	Max. 3.75 L/ha
Adlerfarn	Hoestar	NT1[illegible]	[illegible]	1 g/10 L water	Summer to autumn
Broadleaf weeds	Banvel M	[illegible]	14 days	4.0-6.0 L/ha	Also common horsetail, no nettles
	[illegible]	[illegible], NT103, [illegible]P681-684	7 days	2.0 L/ha	No cutting in the year applied
	[illegible]d	NT108	28 days	2.0 L/ha	
	Harmony SY	NW5, NT103	14 days	45 g/ha	Not over 25°C
	Taipan	NW5, NT108	21 days	1.8 L/ha	Does not protect clover
Sorrel, dandelion, nettle	Ranger, Garlon	NW5, NT103	14 days	2.0 L/ha	Before weeds flower
Dandelion	Calcium cyana-mide			300-400 kg/ha	During budding on dewy leaves

8.3 Animal pests

There are many animals that feed on grasses and their roots. This is generally not a problem as long as moderate amounts of feeding occur; but if the frequency increases, these animals can become pests and lead to considerable losses. This section lists the most important pests.

8.3.1 Wireworms, beetle larvae, gnats

Controlling different larvae, such as those of gnats, click beetles or cockchafers only becomes necessary when they cause significant damage. They cause damage by consuming roots or the storage organs of short grasses. Infestations can be reduced by calcium cyanamide or by applying beneficial nematodes. In particularly severe cases, partial replanting is recommended. Tilling and loosening the soil causes eggs and young larvae to become exposed to the light and dry out.

Application of calcium cyanamide

8.3.2 Water voles

Especially during the winter, voles cause damage through their feeding and digging. Control measures can take different forms depending on the intensity.

As ever, an ounce of prevention is worth a pound of cure. Significant autumn growth doesn't just provide ample hiding places for these voles but also protects them from the effects of the weather and offers plenty of food. This highlights the importance of ensuring that the grassland is well maintained before winter starts.

In smaller infestations, the installation of vantage points for birds of prey has proven to help keep the vole population in check. If the damage becomes widespread, however, they must be actively controlled. Treating the field by spraying in such cases has been prohibited for several years. A dispensing gun (such as those offered by frunol delicia®) can be used to place poisoned bait pellets in each individual hole. Five seeds/pellets per hole should be enough. The poisoned bait pellets should always be well hidden in the entrances, in order to prevent them from being eaten by birds or wild animals. On large fields, the bait pellets can also be distributed over large surfaces using a specialised plough, which digs an artificial walkway beneath the grass sward, placing a bait pellet every 5-10 m.

The classic bait boxes are an additional way to place especially large amounts of pellets in a single place. It is highly recommended that control measures start early, since the expense and duration of these measures is considerably higher when begun at a later date.

Applying water vole bait pellets

The European water vole

Water vole damage

8.3.3 Damage by wild animals

The most well-known and widespread wild animal damage is caused by the wild boar (Sus scrofa). These not only cause yield losses, but also contaminate fodder and make it difficult to drive on the field. In addition, depending on the subsoil and the forcefulness of the rooting activity, this damage can also adversely affect mowing machinery. Fodder contamination can have a negative effect on the digestibility of fodder as well as the fermentation processes for silage.

Avoiding these damages is not always a simple matter, since they often come about as a result of mast years in the forest. Wild boars attempt to balance out their lack of protein by consuming beetle larvae and worms (see Chapter 8.3.1) on grassland fields. Thus, grasslands can see impacts from wild animals even in years with ample forage in the forest. On intensively utilised fields, hunting can have a deterrent effect, especially on juvenile wild boars. Fencing in fields is generally not effective. The use of odorous substances as deterrence has met with mixed results. They often work for only a short period of time, but can at least initially prevent damage. One interesting experience in preventing damage comes from Bavaria. There, it was determined that special sulphur pellets were able to significantly reduce damage to grasslands due to their long-lasting scent, which suggested the presence of danger. It is crucial that any damage by wild boars be levelled. This can be done using rakes or harrows. The Wiesenengel® is one new innovation for eliminating wild animal damage. The system evens out the stand in a single operation and can also carry out reseeding at the same time as it rolls the surface. This innovation helps to protect the field by bringing together several activities in a single set of equipment. The advantages of Coated Seed become particularly clear under these conditions.

The increased TGW helps to ensure precise administration, as well as soil contact in a challenging seed bed. Selecting the right grasses is crucial, though only highly

Wiesenengel® to prevent grassland damage

Left: untreated/Right: treated

competitive varieties of perennial ryegrass are suitable for planting. The cleared areas, generally quite attractive to birds, are not an issue, since Coated Seed is particularly unpalatable to birds.

Wild boars have caused significant damage here

Aerobic	Metabolic processes in which oxygen is required are referred to as aerobic.
Anaerobic	Metabolic processes in which oxygen is not required are referred to as anaerobic.
ASN	Ammonium sulphate nitrate (ASN) is the most frequently used sulphur-nitrogen fertiliser. It contains 26% nitrogen and, depending on the manufacturer, between 13% and 15% sulphur in the form of sulphate.
Assimilate	The energy stored by a plant is referred to as assimilate. It consists of all the products that the plant produces through photosynthesis. Generally, they are stored in the form of glucose.
Broad-spectrum herbicide	A substance for weed control with a non-selective mode of action, meaning that it kills all plant species.
CAN	Calcium ammonium nitrate (CAN) contains 27% total N, half of which is in the form of ammonium and the other half as nitrate. It can also contain up to 4% MgO.
Chlorosis	Chlorosis is a symptom of disease or nutrient deficiency in terrestrial plants that is characterised by a lack of chlorophyll. The disease is clearly visible due to its characteristic pattern of damage.
Coated Seed	A seed technology involving the application of various materials around the seed in order to improve germination conditions and plant development.
Cross Compliance	Cross Compliance is a policy where farmers are required to fulfil particular obligations in areas of environmental conservation, animal welfare and human, animal and plant health to be able to avail benefits of certain EU agricultural payment schemes.
Diploid	Living organisms with two matching sets of chromosomes.
DM	Dry mass or dry matter; an indication of the weight of plant matter in the total absence of water.
Extensification	Processes that reduce the use of commercial factors of production in relation to a given standard or a previous point in time.
Feed value	Feed values, conceptualised by Klapp et al. (1953), is the oldest existing means of appraising the suitability of grasses for fodder to be used in cattle feed. The 10-point scale was developed to assign feed values (Wertzahlen, WZ) that range from -1 (poisonous) to 8 (highest feed value). The criteria include: • Protein and mineral content • Palatability • Share of valuable plant components • Suitability for utilisation • Toxicity
Fungicide	Substances to control fungi and spores.
Gleysol	A soil affected by sub-surface water.

Harmful soil compaction	Harmful soil compaction refers to the severe or irreversible increase in the compaction level of topsoil and subsoil.
Herbicide	A substance for controlling weeds.
Indicator plant	Plants whose occurrence indicates the existence of certain soil characteristics, contamination or nutrient status.
Inflorescence	Reproductive component of the plant which forms flowers and is often considerably offset from the shoot axis.
Insecticide	A substance for controlling insects.
Lamina	The flat surface of the leaf.
Lamina	Also known as the leaf blade, it forms the main part of the leaf and is where photosynthesis occurs.
Leaf base	Part of the vegetation cone (focal point of growth) whose outer cells undergo differentiation to form the leaf base and emerge as the youngest shoot.
Leaf node	Point of contact between the leaf and the shoot axis of the stalk.
Legumes	A plant family (Leguminosae) that is able to fix atmospheric nitrogen through a symbiosis with bacteria.
Lignification	Storage of lignin in plants' cell walls, leading to a woody texture.
Ligule	A thin membrane present in plants with leaf sheaths, which is attached to the transition between the sheath and the upper side of the leaf blade.
LUFA	The North Rhine-Westphalia Agricultural Research Centre (Landwirtschaftliche Untersuchungs- und Forschungsanstalt Nordrhein-Westfalen).
Mast year	Trees that contain very energy-rich seeds tend to undergo cyclic fructification (fruit formation) in so-called mast years.
Maturity group	A classification of available varieties based on when they form inflorescences.
Meadow	Grasslands primarily characterised as being used for mowing.
ME	Metabolisable energy refers to the total usable energy available to cattle from fodder.
Meristem	Also known as the cambium, this is a type of plant tissue that consists of undifferentiated cells and can be involved in growth through cell division.
Microbial	Caused by microorganisms (mostly bacteria) or relating to microorganisms.
Necrosis	A term relating to the death of tissue due to metabolic disorders, poor nutrient supply or the effects of toxins, sun rays, heat and freezing conditions.

NEL	An abbreviation for the term "net energy lactation". Expressed as a number and unit, usually joules per kilogram, this measurement indicates the energy content of animal feed that can be used in milk production.
N fixation	Only a few plants are able to enter into a symbiotic relationship with nitrogen-fixing bacteria and thus use atmospheric nitrogen for plant growth. This symbiosis between leguminous plants and various strains of bacteria involves reducing atmospheric nitrogen (N_2) to ammonia through a microbiological process that uses the nitrogenase enzyme and energy. Studies have reported rates of N fixation of 50-700 kg N/ha/year.
Nitrification	Nitrification is the term used to describe the oxidation by bacteria of ammonia (NH_3) and ammonium ions (NH_4^+) to nitrate (NO_3^-).
NWL	Association of the Chambers of Agriculture of Northwest Germany.
Pasture	Grassland primarily used for grazing.
Peatland (moor, fen)	Also referred to as peaty soils: mineral soils that contain high percentages of organic matter due to excess water and a lack of oxygen.
Permanent grassland	Forage production areas that contain the same plant population over a long time period (> 5 years).
Plant community	A typical collection of different species in association with an ecological location.
Ploidy	The ploidy figure indicates how many matching sets of chromosomes an organism has.
QSM	Quality standard mixtures.
Regrowth	Growth of grasses after being successfully grazed or mowed.
Rhizobia	Root bacteria that enter into a symbiotic relationship with leguminous plants and make atmospheric nitrogen available for plants.
Rhizome	A lateral shoot that grows underground, from which a new plant can emerge in a form of vegetative reproduction.
RHT	Seed mixtures recommended by the Association of Grassland and Forage Cultivation of the federal states in the German Central Uplands.
Runner-forming/ sucker-forming	Plants that form runners (also called suckers or stolons) are called runner-forming.
Sexual (reproduction)	Sexual reproduction involves the combination of genes from multiple individuals, resulting in a genetically separate individual.
Short grass	Grasses that form a large amount of low-lying leaves and few flowering stalks. Primarily found on pastures.
Silage	A type of forage preservation based on lactic acid fermentation under anaerobic conditions.

Soil quality	Information that provides insight into the soil's yield capacity. Depends on the soil type, type of formation and the current status. Frequently expressed as soil points.
Soil types	S Sand LS Loamy sand SSi Sandy silt VSL Very sandy loam LSi Loamy silt SL Sandy loam SiL Silty loam L Loam SiCL Silt clay loam CL Clay loam C Clay
Stolons	Runners.
Stoma/stomata	A stoma is an opening or pore in the epidermis of plants. Stomata are generally made up of two bean-shaped cells called guard cells.
S/BC ratio	The ratio of sugar content to buffer capacity. The S/BC ratio describes the acidification potential of plant material.
Tall grass	Grasses that are characterised by their large number of flowering stalks, with leafy shoot axes and few low-lying leaves. Found mainly in meadows.
Temporary grassland	In contrast to permanent grasslands, only used for fodder production for short periods (< 5 years) and on fields used for crop production.
Tetraploid	Living organisms with four sets of matching chromosomes.
TGW	Thousand grain weight.
Tillering	Branching at the base of a plant's stem, especially common in grasses. Leads to the growth of several lateral shoots.
Tuft-forming	Several stems of a single plant grow together in a group, forming a structure called a tuft.
Utilisation frequency	The number of times a grassland is cut or grazed per year.
Utilisation intensity	The frequency with which a grassland is cut or grazed.
XA	Raw ash.

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