Ecosystem Health and Sustainable Agriculture

Sustainable Agriculture

Editor: Christine Jakobsson
Planning of Sown Grasslands

Pastures

A prerequisite for establishing sown pastures is the presence of suitable land around a farm. Efficiency of the use of pastures is significantly influenced by the area of conjoined pasture plots and their location on the farm(s). Large pasture plots close to the farm make it easier to arrange grazing and reduce the expenditure on cow lanes, fences, watering points etc (Figure 40.1). The distance between the farthest part of the pasture and the farm should generally not exceed 2 km. Too long a distance from the barn to the pasture and back causes a decline in milk production. The area of sown pasture is planned according to the type of enterprise and the number of animals. The main factor affecting animal productivity and weight gain is the amount of grass eaten by an animal – intake. It depends on the palatability of grass, which in turn is mainly affected by the botanical composition of the pasture, developmental stage of plants and the amount of fertiliser applied. In addition, intake is strongly affected by grass supply, animal weight and appetite, health condition, age, milk yield and several other factors. As a rule of thumb, the daily intake of grass dry matter by a dairy cow comprises about 2.5-3% of its live weight. Consequently, a highly productive dairy cow needs about 80 kg high quality pasture grass per day. Daily feed requirement should be partly covered by roughage with high dry matter content. The grazing area per animal should be about 0.6 ha, provided that the average duration of the grazing period is 160 days and the dry matter yield of legume-rich sown pasture in the vegetation period is 5-6 tonnes per hectare (30-35 tonnes as green fodder). It should also be taken into account that the distribution of grass yield during the vegetation period is uneven and that 20-25% of high quality grass remains unused due to dung patches and treading. It is inevitable that in spring, during periods of most intensive grass growth, there is a lot of excess grass which should be ensiled, especially on sites located far from the farm. Consequently, it is reasonable to plan for most of the pasture area to be used rotationally for both grazing and silage-making. When planning sown pasture for young cattle, it should be considered that the area required is 70-100 m² per calf and 1,500-2,500 m² per heifer.

For grazing young cattle, a uniform pasture area, which need not be located in the immediate neighbourhood of the barn, should be established. During the grazing period young cattle do not necessarily need supplemental feed or shelter. After having calculated the amount of summer feed needed by the cattle and the area of relevant pastures, it is necessary to check whether there is sufficient land stock for establishing the pastures. Specific features and soil types of the area in the immediate neighbourhood of the already existing barns are predetermined. The exception is establishment of a new farm. Planning of grasslands is based on knowledge of soil properties.
Data needed for planning the types of grasslands and rational use of land stock include:

- Relief of land surface.
- Type of soil.
- Soil acidity - $\text{pH}_{\text{KCl}}$.
- Water regime.
- Soil nutrient content – mainly that of phosphorus, potassium, calcium, organic matter.
- Previously applied rotation of crops.

In order to get a reliable overview of the nutrient content of soil, samples for chemical analysis should be taken from the top 20 cm soil layer. As establishment of sown grasslands is relatively expensive, it would be wrong to think that they can be located on unfertile lands which are unsuitable for cultivating other crops. It is reasonable to establish sown grasslands on flat or evenly sloping land plots where snow melt water cannot accumulate in early spring. The soil should be rich in nutrients and if necessary, also drained.

**Meadows**

Multi-cut sown grasslands are established mainly for supplying cattle with winter forage, but today also more and more for making year round forage – silage. In some cases it is necessary to make hay as well. In planning mown meadows, the (winter) feed requirement of the herd and feed quality should be considered. A rule of thumb says that:

- The planned amount of high quality silage should be 12-13 tonnes per cow.
- If dairy cattle nutrition is based on year-round silage diet, the amount of feed needed per cow should be increased to 15 tonnes.
- Feed requirement for young cattle should be considered as well.

To simplify the planning of areas needed for grasslands, average yields of the main types of sown meadows are given in Table 40.1.

**Table 40.1. Average yields of forage crops.**

<table>
<thead>
<tr>
<th>Silage crop</th>
<th>Approximate yield, DM tonnes/ha</th>
<th>Area of sown grassland needed for making 1,000 tonnes of prewilted silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red clover + timothy</td>
<td>5...7</td>
<td>50</td>
</tr>
<tr>
<td>Lucerne</td>
<td>6...7</td>
<td>45</td>
</tr>
<tr>
<td>Italian ryegrass</td>
<td>6...8</td>
<td>40</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>7...8</td>
<td>40</td>
</tr>
</tbody>
</table>
Choosing Seed Mixtures

A properly formulated grass seed mixture is essential for establishing permanent pasture herbage with high nutritive value and fast regrowth. In formulating pasture mixtures, the effect of grazed animals on herbage development and botanical composition, as well as competition between species, should be considered. Only grass species and varieties that are tolerant to grazing and competition between species should be used.

The next step in choosing species and varieties in the pasture grass mixture is to define the objective of the pasture establishment and the way of using the pasture – which animal species will be grazed and which other purposes the pasture will fulfil.

Pasture grass should be highly palatable for the grazing animal species – with high intake and nutritive value. Timothy among the tall grasses and perennial ryegrass among the low grasses have the highest palatability, nutritive value and resistance to grazing. Leguminous plants play an important role in increasing palatability and nutritive value of pasture grass. The most widespread forage legumes that tolerate grazing are white clover, bird’s-foot trefoil and lucerne varieties for pasture. Pasture sward should be dense and resistant to treading. Therefore in pasture mixtures low grasses such as perennial ryegrass,
smooth-stalked meadowgrass and red fescue play an important role. Low grasses create dense low herbage undergrowth and a sward resistant to grazing. Low grasses prevent the invasion of weeds and other unsown herbaceous plants to pasture sward. In order to get permanent sward in given growing conditions, grass and legume species should be selected according to the soil type and local growing conditions. Usually soil characteristics do not constitute obstacles to the establishment of grasslands, as there is a wide choice of grass species and varieties suitable for growing on different soil types (Table 40.2).

The main soil characteristics are:

- Soil reaction: acidic pH_{KCl} <6.5, neutral pH_{KCl} 6.6-7.2 or alkaline pH_{KCl} >7.2;
- Soil texture (light, heavy, peaty etc.);
- Soil water regime (dry, moderately humid, temporarily waterlogged etc.)

Although seed companies offer ready-made seed mixtures, in many cases it is rational for the producers to formulate the mixtures themselves as the growth conditions and usage objectives of grasslands may vary greatly.

Multi-species mixtures have proven to be more efficient than pure swards. Although in Western Europe (England, the Netherlands) pasture mixtures for dairy cows and sheep mainly contain the seeds of different varieties of perennial ryegrass, pure perennial ryegrass swards are quite sensitive to winter damage. Therefore sowing seeds as monocultures to establish a pasture is rarely recommended. Properly chosen companion species in the mixtures increase the nutritive value and intake of herbage and lengthen the duration of the grassland. Winter damage and weed infestation have been found to be less severe in mixed grassland swards than in pure swards.

The use of forage legumes, mainly white clover and treading-resistant lucerne varieties, in seed mixtures has proven to be effective regarding aspects of economy and sustainable agricultural production. Air nitrogen bound by the root nodules of legumes helps save expenditure on nitrogen fertilisers. Leaching of nitrogen compounds into the groundwater is reduced as no nitrogen fertilisers are applied. Legume-rich pasture herbage (legumes comprise 30-35% of DM yield) which has not been treated with nitrogen fertilisers gives the same yield as a grassland to which 200 kg nitrogen per hectare has been applied. Legumes increase the nutritive value (mainly protein), palatability and intake of pasture grass. Many field trials have shown that increasing the percentage of white clover in the herbage results in an increase in daily weight gain of cattle and in milk yield of dairy cows. Increasing the percentage of white clover in pasture herbage by 10% has been reported to increase daily milk yield by 0.30 to 0.45 kg per cow.

Use of forage legumes in pasture mixtures is mainly restricted by acidic soil (pH_{KCl} <6.0 for lucerne, especially) and either too wet or too dry soil regime. White clover has also a shallow root system, which makes it intolerant of long drought periods. Another disadvantage is the quite short duration of white clover grasslands – in Estonia the average duration of sown white clover is 5 years. If the content of legumes in dry matter yield of pasture grass drops below 20%, the grassland should be re-seeded. If the composition and density of grass are suitable, the pasture can be treated with nitrogen fertilisers and its utilisation may be continued. If the percentage of valuable forage plants in pasture herbage is low (below 30% in DM), direct seeding of legumes into the old sward should be considered as well.

Simultaneous growing of legumes and grasses reduces the risks arising from unfavourable weather conditions. Legume-rich pastures should constitute 50 to 80% of the total area of sown pastures.

As to pasture utilisation schedule, it is essential to establish pasture swards which have different rates of development. This allows spring grazing to be started earlier and prevents a situation where the entire herbage simultaneously reaches the stage of development suitable for grazing. The growth and development rate of pasture herbage can be regulated by growing different grass species or by using early, intermediate and late grass varieties.

Smaller areas in the immediate neighbourhood of farms should be seeded with grass mixtures which have rapid initial development and regrowth in spring. Suitable dominant grasses can be cocksfoot or meadow foxtail, as both compete strongly with other species and have a high development rate. Pastures dominated by cocksfoot can be established in dry habitats and those dominated by meadow foxtail in moist habitats. It must also be men-
tioned that the duration of swards rich in those grasses is very long – over 10 years.

Long duration of high-quality grasslands is usually profitable as it saves expenditure on reestablishment of grasslands. At the same time, breeding of grass varieties is being directed to maximally intensive yield consumption. Sowing early in spring enables up to two-thirds of the potential annual yield of herbage to be obtained. For that reason, the use of ‘short- and long-duration sown pastures’ has decreased.

Today the optimal duration of a sown pasture is 5 to 6 years. At the same time attempts should be made to maintain high-quality herbage and thus elongate its duration. Duration of legume-rich grasslands can be elongated by using long-lived legumes like treading-resistant lucerne varieties in pasture mixtures. For longer duration of pastures it is important to manage the grazing load and avoid intensive treading of the sward by animals or heavy machinery in rainy periods. It is difficult to recommend conventional seed mixtures suitable for establishment of pastures. Producers can choose from a very wide range of different grass and legume species and varieties in order to select a seed mixture proper for growing in specific habitats. Table 40.3 represents some of the recommended seed mixtures which are simple, contain only few species and have a low sowing rate. It was assumed that the germination rate of seeds is 100%.

Key factors which should be taken into account in the formulation of seed mixtures:

• Keep seed mixtures as simple as possible; use grass and legume species suitable for specific soils and habitats.
• Select grass species which are preferred by the grazed animal species.
• Under favourable growing conditions establish legume-rich pasture herbage (legumes comprise 30% of DM yield) covering at least half of the total pasture area.
• Consider the suitability of development rate of grasses for growing in mixtures.
• Do not establish sown pastures as undersown crops in grain.
• For establishing sown pastures, do not use short-lived grass species with high competitiveness such as Italian ryegrass.

### Establishment of Grasslands

The objective of establishing grasslands is to get a sward producing quite cheap but high-quality grass feed. Re-establishment of older grasslands is necessary if the yield and its quality are low. The first indicators of sward ageing can be low yield of grassland and in pastures also poor intake of grass by animals. The grass quality generally declines due to changes in the botanical composition of the sward – loss of high quality grasses and legumes from the herbage, and invasion and spread of unsown herbaceous plants with low yield and nutritive value in the sward.

Frequently, the degradation of the botanical composition of the sward is the result of improper use and management of grasslands, alterations in soil nutrient content, pH and moisture regime. Application of insufficient amounts of fertilisers, delayed mowing or grazing, intensive grazing or using heavy machinery on waterlogged soils can all be reasons for shortening the duration of a high quality sward.

Table 40.3. Seed mixtures for sown pastures (seed germination rate 100%).

<table>
<thead>
<tr>
<th>Grass species</th>
<th>Content in seed mixture, weight %</th>
<th>Seed kg/ha</th>
<th>Total seed mixture kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry gravelly soil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grazing-tolerant lucerne</td>
<td>66</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Timothy</td>
<td>17</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Smooth meadow-grass</td>
<td>17</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Moderately moist mineral soil duration of legume-rich herbage is 5 years, afterwards it is rich in grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White clover</td>
<td>20</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Timothy</td>
<td>40</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Perennial ryegrass (diploid variety)</td>
<td>20</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Perennial ryegrass (tetraploid variety)</td>
<td>20</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Dry mineral soil with heavy texture</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocksfoot</td>
<td>65</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>Timothy</td>
<td>26</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Smooth meadow-grass</td>
<td>9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Moderately moist peat soil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timothy</td>
<td>42</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>42</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Smooth meadow-grass</td>
<td>16</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Depending on a climatic zone, grasslands may be temporarily damaged by winter cold, especially snowless and frosty winters, lasting spring meltwater and its icing, and also abrupt fluctuations in air temperature in early spring. Grass cultivars imported from warmer climatic zones are especially susceptible to such weather conditions. Loss of short-live grass species from the herbage is unavoidable.

Ageing of grasslands is a natural process and the optimal duration of the herbage depends mainly on selected/sown grass species and varieties as well as on usage regime and climatic conditions.

**When to Re-establish Grassland?**
Re-establishment of grassland is very expensive. It should be undertaken only if the botanical composition of the sward has degraded, the grassland needs to be levelled or the soil needs to be drained. Re-establishment of grasslands is justified if the costs involved are repaid by the subsequent higher yields of better quality. Grassland renovation is needed if:

- The sward contains less than 50% high quality grasses.
- The sward contains more than 30% unsown forage herbs and weeds.
- The soil surface is very uneven.
- The sward has been severely damaged by cold or heavy tilling machines.
- Soil drainage is urgently needed.

The quality of the sward decreases rapidly due to the spread of dandelion, couch grass and other herbaceous weeds. Grasslands with medium quality botanical composition (50-70% quality species and less than 25% couch grass) can be improved by using an appropriate technology and usage regime. However, this kind of improvement may take several years.

Establishment of grasslands by reseeding is the most effective method for renewing old and weedy grasslands (meadows, pastures). As reseeding is preceded by sward destruction, it is possible to incorporate organic fertilisers into the soil, level the soil surface and select the botanical composition of herbage according to the growth conditions and producer’s needs.

Re-establishment of grasslands allows the seeds of weeds and unwanted grasses to be ploughed into the lower soil layers. The soil surface can also be further levelled by appropriate tillage.

**Tillage Prior to Reseeding**
Besides correctly formulated seed mixtures and selected seed material, it is very important to apply suitable tillage techniques.

**Soil cultivation in autumn**
As regards tillage prior to sowing, to the first considerations are autumn ploughing in the previous year and determination of fertilisation rate on the basis of soil analysis. Autumn ploughing in September or October is inevitable for re-establishment of old and weedy herbage. On grasslands use of semidigger or breaker ploughs is recommended. The ploughing depth is usually 22 to 25 cm. Harrowing of the grassland prior to ploughing by disc harrow is not always necessary and can even be detrimental if the percentage of couch grass in the sward is high, as rhizomes of the couch grass are multiplied. After the sward has been turned over, it must have enough time for decomposition. Therefore ploughing in early autumn is more effective than ploughing in late autumn. On peat soils and on soils with heavy texture, it is recommended to plough at least by July as decomposition of the old sward takes place more rapidly in warm soil.

**Use of herbicides**
When the existing grassland contains couch grass, dandelion, stinging nettle or other forbs, these should be wiped out using herbicides before ploughing. The most widely used herbicide is Roundup or Roundup Bio – a systematic herbicide (active ingredient glyphosate) for long-lived weeds. In order to maximise the effect of glyphosate, couch grass should have at least 3 or 4 green leaves and be 10 to 15 cm high. Weeds should be sprayed in dry weather. The application rate of Roundup is 3-4 litres per hectare and the effect becomes apparent 10-14 days after spraying. Soil cultivation of fields treated with Roundup may be started after the weed mass has completely browned – 2 to 4 weeks after spraying, depending on the time of spraying.

**Solid organic fertilisers** (manure, compost) should be applied prior to autumn ploughing and liquid manure
(slurry) during soil cultivation in spring. Application of organic fertilisers is particularly important for establishing grasslands on eroded soils and other soils poor in humus.

The recommended application rate for organic fertiliser is 40 to 60 tonnes per hectare. Organic fertiliser applied prior to sowing and by top-dressing at lower rates, e.g. 20-30 tonnes per ha in the following years stimulates microbial processes in the growth environment of the roots and supplies soil with essential nutrients. Soil samples must be analysed for nutrient content and acidity – an important indicator of the growing environment.

Application of agricultural lime to acidic soils (pH<6.0) prior to sowing is essential if legumes or legume-rich seed mixtures are used. Forage legumes are very susceptible to soil acidity. For growing legumes, agricultural lime should be applied if $\text{pH}_{\text{KCl}}$ in the top layer of soil (up to 10 cm) is below 6.0. For growing grasses, lime should be applied if $\text{pH}_{\text{KCl}}$ is below 5.5. Few peat soils need liming if the soil $\text{pH}_{\text{KCl}}$ is below 5.0.

Agricultural lime should be applied in two portions: the first one prior to autumn ploughing and the other prior to soil cultivation in spring. This ensures that there is contact between lime and seeds in the germination environment. The recommended application rate of oil-shale ash (a liming agent used in Estonia) is 5 to 6 tonnes per hectare. Oil-shale ash gives a quick response after application. Besides calcium, it contains potassium, sulphur, sodium, phosphorus and trace elements such as B, Cu, Mn, Mo, Zn, Co (Turbas, 1996). Soils can be also limed with cement clinker dust (from cement industry), dolomite or limestone meal.

Soil cultivation in spring should be started early in order to create favourable development conditions for grass seeds. Sufficient soil moisture is one of the most important factors for initial development of small-sized grass seeds. Therefore soil cultivation should begin as early as possible – when the soil can bear tractors without being rutted. The first operation should be cultivation, preferably with a cultivator with S-shaped tines, followed by smoothing the soil with a slight float. The first cultivation creates ‘loose soil’. With a light float, micro-grooves on the soil surface are flattened and soil capillaries on the surface layer are ‘covered’ in order to prevent evaporation of soil water from the top layer. This is followed by cultivation. It should be borne in mind that over-cultivation of soil dries out the top layer, which is the germination environment of seeds. The soil cultivation depth in spring is 10 to 15 cm. After ploughing the soil sinks so the depth of the loose layer should be only 5 cm.

If reseeding is planned immediately after cultivation, the soil must be rolled to ensure an even sowing depth of the seeds. An important operation prior to sowing after the last soil cultivation is clearing the field of stones.

Optimal Time for Sowing Grass Seed

For germination of seeds and fast development of plants, a certain temperature and degree of humidity are needed. Optimal sowing time depends mainly on climatic and soil characteristics of the region. In Estonia, early spring or late summer is the best time to sow grass seed.

Sowing in early spring provides favourable growth conditions for grasses due to the high moisture content of soil. Sufficient moisture content in the upper soil layer is one of the most important factors for successful establishment of grasslands. On grasslands established at the end of spring or beginning of summer (end of May to end of June), weed infestation can be severe, especially from wind-born dandelion seeds falling on bare soil. As a result, besides having moisture deficiency, these types of grasslands are often weedy.

Sowing in early spring has the advantage over late summer sowing that the grassland can be mown or grazed in the first year of use.

The main advantage of sowing in summer (July until early August) is systematic weakening and disturbance of weeds by soil cultivation (mainly rhizomes of couch grass). Simultaneously, the surface of soil is levelled and favourable preconditions for establishing a weed-free sward are created. In Estonian peat soils, sowing is suggested to take place in summer. However, the greater expenditure accompanying soil cultivation during the spring-summer season should be considered. However late summer sowing should not be delayed too long, as grasses and legumes must have enough time for storing reserve nutrients for winter months. Legumes are particularly sensitive to late sowing. In Estonian climatic
Production of High Quality Products & Balanced Feeding

conditions, forage legumes should not be sown later than August 5 in order to avoid out-wintering risks.

Reseeding Methods for Establishing Grasslands
Well-prepared soil for sowing should be level, sufficiently compacted and loosened to a depth of 20-30 mm. The well-compacted lower soil layer provides seeds with sufficient moisture and creates favourable conditions for the development of young plants. Constant sowing depth plays an important role for uniform germination of grass seeds. As grass seeds are relatively small, the optimum depth of sowing ranges between 10 and 20 mm. Such a sowing depth can be achieved by preparing smooth and shallowly loosened soil. Table 38.4 shows the effect of sowing depth on the germination of grass seed.

Compacted soil and a smooth soil surface create good conditions for sowing at even depth, guarantee good carrying capacity and result in the new sward being more resistant to animal treading and wheel traffic of agricultural machinery. The smooth soil surface also allows a low and even mowing height in the period the grassland is used.

For preparation of soils (particularly light and peat soils), the use of rollers after the last cultivation is recommended in order to compact the soil. On mineral soils, rifflle land rollers have the advantage over flat rollers since they crumble chunks of the upper layer of soil and compact the soil more efficiently.

Drilling. For sowing in drills, special grass drills are recommended. The distance between drill coulters should be up to 75 mm and sowing depth 2 to 3 mm for grasses, and up to 2 mm for grass/clover mixtures.

Broadcast sowing. Satisfactory results can also be achieved by using a grain seed drill after removing the coulters – seeds are broadcast on the soil surface where they are covered with soil by the following harrow. Irrespective of sowing method, the seed drill must be fitted with a light harrow. Rolling the soil after sowing plays an important role in creating favourable conditions for plant development. Rolling is not recommended after rainfall when soil is wet. It is also important to choose a suitable weight of roller – on peat soils heavier rollers are needed.

Resowing of Grasslands in Cover Crops
Reseeding in a cover crop is an opportunity to attain the maximum yield per area unit. It is recommended that leys (red clover+timothy) be established by undersowing in a cover crop. Early ripening barley varieties are usually used as cover crops. However, the seed rate of barley should be lowered by 25-30% and application of nitrogen fertilisers is not recommended. Grass seed may be sown simultaneously with the cover crop or later when the cover crop is at 2- or 3-leaf stage. Undersowing in a cover crop has several disadvantages: shading of grass seedlings by cereals, competition for soil nutrients and water, the cover crop may be prone to lodging, etc.

Pasture swards should not be established under a cover crop, as e.g. white clover, low grasses and lucerne are particularly sensitive to the effects of the cover crop.

When establishing grassland, it is necessary to:

- Determine soil pH and nutrient content.
- Select seed mixture according to the use of grassland and the type of soil.
- Use simple seed mixtures.
- Pay attention not only to the species but also to the VARIETY of the grass seed in the mixture.
- Avoid purchasing seeds of unknown origin.
- When establishing grassland for rotational usage, it is reasonable to choose a seed mixture suitable for grazing as well as for silage-making.
- Avoid red clover in pasture mixtures.
- Include Italian ryegrass in the mixture only if there is an "urgent need".
- When sowing perennial ryegrass choose moderately moist and fertile soil.
- Avoid delaying sowing.

Table 40.4. Effect of sowing depth on germination of white clover and perennial rye-grass (Frame et al., 1998).

<table>
<thead>
<tr>
<th>Sowing depth (mm)</th>
<th>Germination (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White clover</td>
</tr>
<tr>
<td>10</td>
<td>81</td>
</tr>
<tr>
<td>20</td>
<td>63</td>
</tr>
<tr>
<td>30</td>
<td>41</td>
</tr>
<tr>
<td>40</td>
<td>12</td>
</tr>
</tbody>
</table>
• The soil surface should be only shallow-loosened prior to sowing. Seeds should not be sown too deep.
• Sowing should be timed so that emerged young seedlings are not exposed to draught.

Grassland Management in the Year of Sowing

After creating favourable germination conditions for grass seeds, it is essential to ensure subsequent continuous fast development of young grass plants. The initial management technique for reseeded grasslands without a cover crop is topping to control weeds. Weeds compete with crops for nutrients, light and water. Infestation by annual weeds on reseeded grassland is rather frequent and therefore it is necessary to cut the herbage at a height of approximately 15 cm. Cutting at that height does not disturb crop plants but inhibits the development of weeds and prevents the maturing and spread of seeds.

Weed topping in the year of sowing must not be delayed as the mown biomass may cause ‘suffocation’ of crops and create gaps in the sward. However, if the spread of weeds is not a problem and crops are not shaded by them, it would be more reasonable to harvest the first cut together with weeds as green fodder. In some cases, e.g. with ephemeral dicotyledonous weeds, it may also be necessary to apply chemical herbicides on newly established grasslands (e.g. Basagran, application rate 2.5-3.0 litres per ha).

After one or sometimes two toppings, the grassland is ready to be grazed. Grazing of spring-sown pastures should start in the second half of summer by grazing young cattle under dry weather conditions. It is important to let the plants form a thick sward and give them enough time to develop a root system in order to create a sward resistant to treading by animals. Grazing of pastures on rainy days when soil is very wet is not recommended. The crop should be harvested for use as green forage or silage material.

Before wintering, the sward must not be too low or too high (min. height 7 cm). Late and intensive grazing or mowing is to be avoided.

Use of Mineral Fertilisers for Establishment of Grasslands and on Harvest Years

Application of mineral fertilisers to grasslands is mainly affected by nutrient content of the soil and grass species in the sward.

Regarding economic as well as ecological aspects, it is first necessary to take average soil samples in the field and draft a fertilisation plan on the basis of chemical analyses. If for some reason organic fertilisers were not applied prior to ploughing, it would be necessary to use mineral fertilisers for establishing grassland with high quality and stable yield.

For plants, the balance of the major nutrients in soil is essential. Deficiency of even a single nutrient in soil can result in a decrease in crop quality, yield and winter hardiness. When re-establishing old and unfertilised (semi-natural) grasslands, particular attention should be paid to the potassium content of soil, as grasses need high amounts of this element.

For forage legumes, especially pure stands of lucerne, it is important to pay attention to the content of calcium (Ca), phosphorus (P), sulphur (S), boron (B) and magnesium (Mg). Phosphorus (P) and potassium (K) or complex fertilisers should be applied prior to seeding during spring or summer tillage according to the soil nutrient supply. Mineral fertilisers should be applied in spring, after the soil has dried and before the last cultivation, as then the fertiliser is mixed into the top layer of soil. If necessary, agricultural lime should be applied during cultivation.

In harvest years, PK fertilisers are applied to grasslands by top-dressing in autumn after the last cut or grazing. Table 40.5 presents limit values of P and K content in mineral soil and recommended P and K application rates.

Higher rates of PK fertilisers (P 45-55 and K 125-150 kg per ha) are recommended on peat soils as they are usually much lower in phosphorus and potassium than mineral soils. Peat soils are also poor in copper (Cu) and need to be treated with fertilisers containing Cu if this is possible or required.

Application of nitrogen fertilisers – in the form of ammonium nitrate, ammonium sulphate, and urea – is necessary mainly for swards consisting of grasses. N fertilis-
Table 40.5. Limit values of K and P content (determined by using A-L method) in mineral soil and recommended P and K application rates for grasslands

<table>
<thead>
<tr>
<th>Content</th>
<th>P mg/kg</th>
<th>K mg/kg</th>
<th>Recommended nutrient application rates, kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>leguminous-rich herbage</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>K</td>
<td>P</td>
</tr>
<tr>
<td>Very low</td>
<td>&lt;20</td>
<td>&lt;50</td>
<td>26</td>
</tr>
<tr>
<td>Low</td>
<td>21…40</td>
<td>51…100</td>
<td>17</td>
</tr>
<tr>
<td>Medium</td>
<td>41…80</td>
<td>101…200</td>
<td>15</td>
</tr>
<tr>
<td>High</td>
<td>81…120</td>
<td>&gt;200</td>
<td>10</td>
</tr>
</tbody>
</table>

ers are not recommended if the proportion of legumes in yield is more than 30%. Use of moderate N fertilisation rates is inevitable for managing grasslands rich in Italian ryegrass, perennial ryegrass, reed canarygrass, meadow fescue, cocksfoot, timothy and tall fescue. Application of N fertilisers can significantly improve the quality of grass feeds and increase the yield. N fertilisers can be applied in the year of sowing as a top-dressing of herbage and the suggested N application rate is 60-80 kg per ha. Fertilisation with N in late summer (from August) should be avoided – it can stimulate grass growth but reduce winter hardiness and in spring the sward may be damaged. The suggested application rate for top-dressings of N to grasslands rich in tall grasses is 150-210 kg per ha, applied in two or three equal portions during the whole vegetation period.

**Application of Slurry to Grassland. Technologies**

Manure spreading restrictions and establishment of liquid manure storage facilities at large-scale cattle farms have created a problem concerning agronomically effective and sustainable application of slurry as a fertiliser, particularly reducing of nutrient losses during application to land.

**Nutrient Losses from Liquid Manure**

Nitrogen in manure occurs in organic and inorganic forms. Inorganic forms of nitrogen are immediately plant-available but organic compounds can become plant-available through mineralisation in the soil. The largest nitrogen emissions occur through intensive volatilisation of ammonia (NH₃) from field-applied (to crop or grassland) manure. The chemical process is quite simple – urea CO(NH₂)₂ excreted by an animal is hydrolysed into ammonium nitrogen (NH₄⁺-N) by the activity of urease and release of ammonia (NH₃) follows. Emissions of ammonium nitrogen (NH₄⁺-N) as volatilised NH₃ during spreading of liquid manure usually amount to 40-50% of the N content prior to spreading, i.e. nearly half of plant-available inorganic nitrogen (Mattila, 2006). It is known that the greatest losses of NH₃ occur in the first 3-4 hours after application. Emissions of NH₃ continue for at least 3 days, but at one-tenth of the intensity in the first hours after application (Viiralt, 2007).

Ammonia emissions are more intensive with high air temperature and strong winds. Losses of NH₃ are lower from slurry with lower dry matter content, as diluted slurry infiltrates into the soil more rapidly (if soil conditions allow this); ammonium nitrogen (NH₄⁺) is bound by soil and volatilisation of NH₃ decreases. Measurements carried out in England revealed the following relationship: when the dry matter (DM) content of slurry was 3%, emissions of plant-available nitrogen from slurry amounted to 20%, while for slurry with a DM content of 6% and 9%, emissions comprised 35% and 50%, respectively. Organic nitrogen compounds which have leaked from slurry into soil are subjected to ammonification (NH₄⁺) by the activity of specialist bacteria, and later to nitrification (NO₃⁻). Plant material present in slurry partly remains on the soil surface and decomposes, releasing some ammonia. Lack of air in the soil – caused by excessive moisture, compacting with heavy machines, etc. – can lead to denitrification under anaerobic conditions. As a result, nitrogen oxides (N₂O; NO and NO₂) and molecular nitrogen (N₂) are volatilised.
During spreading of manure on grassland, nitrogen losses due to denitrification fluctuate within the range 0.1-30%, depending on climate and soil conditions.

Losses are higher in autumn than in spring. In spring, soil nitrates are rapidly assimilated by fast growing crops and smaller amounts of nitrate are subjected to denitrification. In spite of that, denitrification losses from liquid manure per kg total N are higher than those from mineral nitrogen fertiliser.

If liquid manure is applied in autumn (under winter crops or on grassland after the second or third cut) it is possible that nitrates (NO$_3^-$) formed during nitrification are leached from the topsoil. However, the risk of nitrate leaching is much lower on grasslands than on arable land due to the presence of permanent herbage. In any case, the forage crops (maize included) should not be over-fertilised with liquid manure – otherwise nitrates subjected to leaching are accumulated in the soil by autumn.

The amount of accumulating nitrates in soil is affected by the content of soluble ammonium (NH$_4^+$) in the applied manure. The percentage of soluble nitrogen in total nitrogen is 40-60% for liquid manure and approximately 10% for solid manure (Viiralt, 2007).

**Phosphorus (P)** present in animal manure can exist in inorganic (mostly) or organic compounds. The changes in phosphorus compounds are complex and mainly result from the activity of soil microbes. Phosphorus in the soil is relatively immobile and does not leach readily. However, if annual application rates of liquid manure are higher than the soil’s ability to bind P, organic soluble phosphorus compounds can move in the water-saturated soil down into the groundwater or out into bodies of surface water and result in eutrophication. Phosphorus can also move into the environment with surface runoff.

**Potassium (K)** in the soil is mostly water-soluble and readily available to plants. Water-soluble potassium is absorbed well in heavier types of soil but in sandy soils there is a risk of leaching. Few data are available about negative effects of potassium on the quality of surface water or groundwater. However, there is a risk of over-fertilising grass pastures with excessive potassium applied with liquid manure. Excessive assimilation (twice the level required by cattle) of potassium by grasses at the expense of magnesium creates a risk of hypomagnesaemic pasture tetany of cows (Viiralt, 2007). Other nutrients present in liquid manure are sodium (Na), calcium (Ca), magnesium (Mg), manganese (Mn) and sulphur (S).

**Technologies to Reduce Nutrient Losses During Liquid Manure Management**

The application time and rate of liquid manure application should be determined by the crop nutrient requirements during the vegetation period. Applying liquid manure to grasslands in spring and spring-summer has proven to be more effective. The annual application rate of liquid manure (tonnes/ha) and the rate per application should be determined on the basis of nitrogen content, such that the annual dose of N supplied with liquid manure does not exceed 170 kg N per hectare (Estonian Water Act, § 26 and EU’s Nitrate Directive).

The approximate content of N in liquid manure is 2-4 kg per m$^3$ and consequently the amount of manure per application can be 30-50 tonnes per ha depending on DM and N content in manure. The rather frequent problem is a very wide P:K ratio of 1:5-6 in liquid manure, as optimally it should be 1:2.5. If large amounts of liquid manure is applied to grassland, supplemental mineral P fertiliser should be applied (Viiralt, 2007).

In recent years there have been attempts to find ways of reducing high nitrogen losses from animal slurry during its application. In Finland, three application technologies for unprocessed slurry were studied (Mattila, 2006): (1) broadcast spreading evenly on the soil surface; (2) band spreading; and (3) injection with a spreading device equipped with high pressure pump and special injection nozzles. The application rate of cattle slurry was 44-45 tonnes/ha, containing 7.1% dry matter and 91-95 kg/ha ammonium nitrogen (NH$_4^+$-N). The pH of manure was 7.1.

Over a three-day period, the loss of NH$_4^+$-N from manure after broadcasting was 40% and after band spreading 31%. The loss of NH$_4^+$-N was only 0.4% when liquid manure was injected into closed slots. Losses of NH$_4^+$-N from slurry application were even higher if the slurry had been previously aerated (DM 6.5%) or separated (DM 4.5%) in the manure storage facility – 59% and 42%, respectively. Consequently, these techniques are not effective and the only way for reducing nitrogen losses (volatilisation
of NH$_3$ is application of slurry to grassland with a special injector and to arable land by cultivation.

Application technology also affected the use efficiency of the slurry: 32-37% of NH$_4^+$-N was recovered in grassland yield when injection was used, while for broadcasting and band spreading the corresponding value was 24-30% (for untreated and aerated liquid manure 24-25%; for separated or diluted manure 30%).

As devices for injection of slurry into grass sward are considerably more expensive than band spreaders, economic calculations must be made in order to find out if the increase in yield resulting from significant reduction of ammonia nitrogen (NH$_3$-N) volatilisation covers the price difference between the devices. Incorporation of slurry into topsoil is a much more environmentally friendly technique than broadcasting (Viralt, 2007). After band spreading it is necessary to harrow the surface of grassland with an ecological harrow in order to prevent the formation of a thin film (consisting of undigested feed particles) on the soil surface, which may inhibit air exchange in the soil as well as the growth of young shoots.

**Grazing Management and Hygiene**

Herbage utilisation by grazing animals depends on forage acceptability and nutritive value. Animals have a preference for grasses in either tillering or leaf-tube formation stage. The feed value of white clover does not decrease before the full-bloom stage. Highly palatable forage grass for dairy cows is short, thick and weed-free. Cows spend more time and expend more energy consuming very short (<10 cm) and sparse vegetation, while if the grass has grown too tall and is too mature they choose only leaves and tillers and, despite abundant forage, do not consume enough feed. The optimum height of grass for grazing is 12-15 cm on pastures rich in low grasses and white clover, and 15-20 cm on pastures rich in tall grasses.

Pastures reach spring grazing readiness when the soil surface is dry enough and the forage is 10 cm high. Grazing is started on mineral soil pastures with early-maturing swards. Grazing time on the pastures with highly palatable grass of a suitable height can be prolonged by gradual transition from early-maturing swards to medium-maturing and late-maturing swards. The first grazing cycle should be terminated as soon as the second cycle starts. Forage which is not used for grazing during spring (~20-40% of the whole pasture area) should be harvested and stored as silage or green forage to allow fast grass regrowth for grazing animals. In Estonia, a pasture can usually be grazed 4 to 6 times during summer, depending on onset of grazing, species composition of sward, and weather conditions.

**Grazing Methods**

*Free grazing or continuous stocking* is the oldest grazing method for keeping livestock on a single pasture unit not split up into small paddocks, for longer periods or throughout the grazing season. Due to high stocking the palatability declines as the most palatable plants suffer from continuous trampling and are grazed too short. As a result, the plants are not able to store reserve substances to survive winter and die out. Continuous grazing on sown pastures is unsuitable for cattle, and can only be applied for sheep grazing on natural pastures with low stocking rates.

*Rotational grazing*. Under this system the grazing area is divided into several small paddocks, where cows normally spend 0.5 to 3 days at a time on a scheduled rotational basis. Following the grazing period, animals are moved to another paddock for grazing, and the previously grazed paddock is allowed to rest and regrow. When forage has recovered, reached optimum height and is again suitable for grazing, livestock can move back into the paddock.

For larger herds (over 50 head of cattle) one-day paddock systems are recommended, while for smaller herds (less than 50 heads) 2-day or 3-day paddock systems are suitable. In the latter case, 23-24 or 15-16 paddocks are needed, respectively. The size of one paddock should be 0.2-0.3 ha per 10 cows or 1.0-1.5 ha per 50 cows.

*Strip grazing*. Grazing of livestock in narrow strips of land, generally behind a frequently moved electric fence, further reduces the grazing time of animals on a paddock, and ensures uniform and efficient utilisation of forage species. The one-day rotational pasture can be divided into more strips to apply a rationed grazing system. A new...
grazing area should be of sufficient size for at least a 2.5 to 3 hour grazing period. This is the length of the cattle grazing-resting cycle, during which they should not be disturbed by providing them with fresh pasture. On a basis of grazing time and length of grazing-resting cycle, the daily grazing area of cows should be divided into 3 strips.

To obtain a higher grass utilisation coefficient, cattle can be given a fresh strip of pasture before being moved to a cowshed. In subsequent grazing, hungry cows will return to the same pasture to ensure the most effective use of forage. Applying the daily rationed grazing system requires the routine to be established in spring and maintained throughout the summer.

**Fencing of pastures.** Fences can be used on a permanent or temporary basis. Permanent fences are used on pastures and roadways for livestock. Permanent fences can also be used in paddock fencing, but from the point of view of grazing management and pasture care, especially in the case of strip grazing, mobile electric fences are preferable. Width of the roadway for livestock depends on the livestock numbers, but even in the case of a small herd the roadway should enable a tractor with fertiliser spreader or grass mower to pass to a paddock. Thus, the livestock roadway track should be 4-6 m in width. The same width applies for gates to each paddock, in the nearest corner to a shed.

**Pasture Care**

The first task in spring pasture care is harrowing using a special grass harrow. This breaks up and scatters dung patches, molehills and suchlike to level the soil surface in a pasture. If needed, piles of animal manure and molehills can also be levelled in summer and at the end of the grazing season.

Good pasture management requires mowing of ungrazed herbage 2-3 days after grazing. Low value and noxious plant species, over-mature grasses, and herbage growing in dung and urine patches remain uneaten. Grass cutting helps to control the spread of unfavourable plant species via seeds, prevents overmatureation of valuable pasture plants, and contributes to the uniformity of grass growth, thus maintaining herbage acceptability. To be well maintained, the pasture should be mowed 3 times per summer.

**Grazing of Different Livestock Species**

*Dairy cows* are very selective grazers and only the best quality pasture herbage is eaten. The most preferable forages for cattle are sown pasture swards rich in low grasses and legumes, and swards rich in tall grasses. Grass on improved natural pastures is also an adequate forage for dairy cattle.

Dairy cattle pastures should be on moderately moist soil and be located in the immediate neighbourhood of farms. Long distances (> 2 km) to the pasture and back can cause a 20% decrease in daily milk yield. Taking into consideration the seasonality of herbage growth on mineral and peat soil, two-thirds of the pasture area should be on mineral soil and one-third on peat soil to minimise the negative effects of mid-summer drought periods and cool late-summer weather.

The grazing area requirement depends on forage yield and forage requirement of cows. Depending on milk yield and body weight, a dairy cow needs 60-80 kg pasture grass per day. The average grazing area per adult cow should be 0.5 ha. The optimum supply of mature forage grasses and legumes before each grazing is 6-8 tonnes/ha.

Paddocks for cows should be square or rectangular in shape. It should be borne in mind that depending on breed and forage yield, a dairy cow spends 6-12 h/d grazing, 6-9 h/d lying and ruminating, 1-3 h/d walking on pasture, 1-2 h/d standing and ruminating, and 0.2-0.4 h/d drinking water. Cattle do most of their grazing in early morning and late afternoon. At noon and after sunset, cows graze for only a short time. Besides grass forage, high-yielding dairy cows need 100-250 g concentrate supplement per kg milk yield.

During the grazing period, dairy cows also need roughage rich in dry matter. This is of particular importance during the 10-12 days of early spring transition from cowshed to pasture, and from grazing to cowshed in the autumn. Abrupt spring transition from fibre-rich winter feed to low-fibre pasture forage causes changes in digestive tract microflora, which induce diarrhoea and other symptoms in cows. As a rule, health disturbances have a negative impact on milk yield, milk fat content and body weight gain of animals.

During the grazing season, cows must have a freely available supply of clean, fresh water, which affects forage consumption as well as milk yield. If adequate fresh
water is available, dairy cows will consume approximately 40 to 80 (maximum 100) litres a day.

Young cattle are not as selective as adult cows with regard to pasture herbage. Young cattle do not consume high-yielding sown pasture grass as effectively as dairy cows. They prefer swards rich in low grasses of sown pastures or swards growing on improved natural pastures. Grazing of young cattle contributes to more effective development of their performance traits, hardens the body and improves their overall health. Young cattle should be grazed in paddocks located some distance away from dairy cows in order to avoid disturbing the dairy herd and to prevent damage to paddock fences. Furthermore, grazing of cows and young cattle on separate pastures reduces the spread of animal diseases.

The land area required to provide adequate herbage for young cattle is 0.15-0.25 ha per animal. The pasture herbage requirement of an animal over one year of age is 30-40 kg per day, and for an animal less than one year of age 15-25 kg per day. Female and male young cattle should be grazed on separate pastures. Subdividing the pasture area into 8-10 paddocks is recommended provided that young cattle are moved from paddock to paddock every 3-4 days. Before the grazing period, young cattle are grouped according to their age as follows: less than one year, 1-1.5 years, over 1.5 years.

Grazing is essential for the normal growth of calves. Calves should be grazed in the neighbourhood of the cowsheds on dry or moderately moist fertile soils. On damp and cold loamy soil pastures, calves are often prone to illnesses. Various supplementary feeds should be provided during the grazing period. Calves should be kept in a cowshed when it is cold and rainy.

Calves prefer to graze swards rich in low grasses of sown pastures that are 10-15 cm tall. The grazing land requirement per calf is 0.08-0.1 ha. Pasture herbage may cover 30-60% of the calf’s feed requirement, i.e. 10-15 kg of grass per calf per day. The pasture area should be subdivided into 8-12 paddocks, with calves moved from one paddock to another every 3 to 4 days. At the beginning of the grazing season calves are grouped according to their age: 1-2, 2-4, 4-6 and over 4 months.

Sheep have the lowest grazing selectivity in what they consume and tend to eat almost all grasses, clovers and herbs. They prefer swards rich in low grasses of sown pastures or swards growing on natural pastures. Pastures for sheep should be located on moderately moist or dry mineral soils. Sheep grazed on damp soil are prone to illness. The grazing area requirement per mature sheep is 0.1 ha. During the grazing season, pasture herbage can completely satisfy the nutritional requirements of sheep. Estimated daily pasture forage consumption of mature sheep is 15-20 kg and that of lambs 2-3 kg. The sheep pasture should be subdivided by use of permanent or temporary electric fences into 10-15 paddocks, with sheep grazing a paddock for 2-3 days. Sheep may spend 24 hours a day grazing. Where pastures are not in the immediate neighbourhood of sheep sheds, sheep shelters should be built. At the onset of the grazing season, sheep should be grouped as follows: (1) ewes with lambs; (2) barren ewes and yearling sheep; (3) rams.

Horses are grazed either in 5-8 paddocks located close to the stables, or post-grazed in cattle paddocks. Horses consume the pasture herbage left uneaten by dairy cows and other animals, thus minimising the need for post-grazing topping of pastures. Horses have a preference for more mature pasture herbage. Grazing is of particular importance for young horses, which, besides pasture forage, also need continuous movement to harden and toughen them up. Mares in early and late lactation are also good foragers on pastures. It should be noted, however, that horses have a grazing behaviour that leaves a relatively large quantity of herbage uneaten due to their avoiding manure-contaminated forage. Their manure tends to accumulate in certain places, which constitute on average 10-40% of the paddock area.

Horse paddocks should be located on mineral soils and have a smooth solid surface to avoid leg injuries. The latter occur more frequently when horses are grazed on peat soils and tufted swards. The estimated pasture area requirement of an adult horse is 0.4-0.5 ha, and that of young horse 0.2-0.3 ha. A horse pasture should be divided into 8-12 paddocks, where horses are grazed on the same area for 3-4 days. A young horse can eat 30-40 kg of pasture forage per day, while an adult horse and a mare with foals can consume 50-60 kg. Horses are divided into the
following grazing groups: (1) mares with foals; (2) young horses; (3) barren mares.

Pig grazing is practised in outdoor production systems for young pigs and breeding swine. Wise use of pasture can significantly lower feed costs. Pigs prefer low-fibre herbage consisting of nearly 70% clovers, and 30% smooth meadow grass and meadow fescue. Young pigs can get 20-40% of their nutritional needs from pasture herbage and barren sows as much as 50%. The estimated herbage requirement is 5-15 kg per pig per day. Swine pastures should be located in the immediate neighbourhood of piggeries, on moderately moist fertile soils. An adequate space for a sow with piglets is 0.18-0.2 ha, and for a young pig 0.1 ha. Swine pasture should be divided into 8-10 paddocks. Pigs should be grazed in the same paddock for 3-4 days.

Chickens, turkeys and geese are excellent foragers, and it is reasonable to keep them on an open-air individual pasture near the poultry farm. When grazed in cattle paddocks, they reduce the herbage acceptability by leaving their dung across the pasture and impair the clovers by too short grazing. Pasture vegetation supplies approximately 60% of the nutritional needs of poultry during summer. Highly suitable forage crops for poultry are low-fibre swards rich in legumes and low grasses. An adequate stocking density is one goose or turkey per 10 m² and one chicken per 1.5-2 m². Poultry pasture should be divided into 15-20 paddocks, with fowls grazed in the same paddock for 1.5-2 days. The daily pasture vegetation requirement is 1-2 kg per chicken and 2-4 kg per goose and turkey. Net fencing (height 1-1.5 m) should be used for poultry.

Parasite Control in Grazing Ruminants
Ruminants pick up infective larvae of parasites by grazing contaminated pastures. Intestinal helminths affect intensive sheep production in damp soils, being even a more significant limiting factor than the poor productivity of grasslands (Frame, 1994). Ewes and lambs mostly suffer from gastrointestinal helminthiasis; typical symptoms are indigestion, weakness, anaemia and extenuation. Severe infection, followed by gastroenteritis, causes considerable productivity losses or even mortality in lambs. During spring and summer grazing, animals become infected with larvae of helminths when grazing contaminated pasture herbage or drinking water from small water bodies. The control of gut worms from the genus *Nematodirus* is problematic since the eggs deposited in pastures with faecal matter stay inactive for extended periods, whereas in summer the hatched larvae become infectious within a couple of weeks (Frame, 1994; Mägi, 2006).

Productivity loss due to helminth infections can be substantially reduced through implementation of effective disease control strategies. An optimum grazing system along with effective environment-saving dosing of anthelmintics should be applied. Distribution of helminthoses is highly regional. It depends on the climatic conditions in various agro-ecological zones and the production system used. The helminth infection rate and disease outbreak risk can be substantially reduced by applying appropriate pasture management systems, e.g. by using pasture rotation – dividing pastures into parcels of land (three more or less equal parts) and moving the animals from one to another on a yearly basis: (1) sheep pasture; (2) cattle pasture; (3) grass cut for hay and silage (zero grazing), or a growing one-year crops. The objective is to avoid putting the animals back into the same field until the risk of infection has diminished. The role of growing grass for silage or a one-year crop in the rotation cycle on pastures is to prevent worm transmission from sheep to cattle and vice versa. Ewes and lambs should not be grazed on the same pastures where lambs or hoggets have been grazed the previous year.

Different control strategies can be implemented in different situations to prevent infections, however, success cannot always be guaranteed. For instance, eggs of gut worms of the genus *Nematodirus* have been shown to survive on pastures in England for several years and the hatched larvae can infect the calves. Therefore, *Nematodirus* from cattle can pose a risk also to sheep despite the use of the above-mentioned three-field or ‘clean’ grazing. Nevertheless, clean grazing reduces both helminth infection and the need for anthelmintics to control parasitism. Long-term data on clean grazing systems in England have demonstrated benefits of the system from several aspects (Frame, 1994): (1) stocking rate increases, i.e. more ewes kept on the same area; (2) higher lamb performance rate; (3) reduced need for
chemicals to control parasitic diseases; (4) better pasture utilisation by cattle and sheep.

Recent studies have demonstrated that in Estonia, cattle are more susceptible to parasites than sheep. Besides intestinal parasites, sheep can also be infected by lungworms. Parasites are picked up more frequently on natural pastures than on sown pastures. All farm animals should be coprologically investigated before the onset of spring grazing period and before autumnal confinement in the barn. Anthelminthic treatment of infected herds, i.e. when eggs of parasites are found in faeces, should be performed (Mägi, 2006). Control measures against helminthoses involve better nutrition, better pasture and grazing management, hygienic natural water bodies or provision of safe well water supplies, and rotational grazing.


