Northern Periphery and Arctic Programme

Northern Cereals – New Markets for a Changing Environment

A Farmer's Handbook for Cereal Cultivation in the Northern Periphery and Artic Region

A Project Report

Deliverable T2.1.3

By

Sæmundur Sveinsson and Jónatan Hermannsson

May 2017

Landbúnaðarháskóli Íslands

Agricultural University of Iceland

Northern Periphery and Arctic Programme
Northern Cereals – New Markets for a Changing Environment

A FARMER'S HANDBOOK FOR CEREAL CULTIVATION IN THE NORTHERN PERIPHERY AND ARTIC REGION - A Project Report

Authors:
Sæmundur Sveinsson[1]
Jónatan Hermannsson[1]

With contributions from:
Ólafur Reykdal[2]
Peter Martin[3]

Northern Cereals Partners:
[1]Agricultural University of Iceland, Árleyni 22, IS-112 Reykjavík, Iceland.
[2]Matís ohf. Vínlandsleið 12, IS-113 Reykjavík, Iceland.
[3]Agronomy Institute, East Road, Kirkwall, KW15-1LX, Orkney, UK.

Table of Contents

1. Cereals

1.1. Main cereal species for northern latitudes

There are six species of cereals that are extensively grown in northern part of Europe: Barley (*Hordeum vulgare* L.), bread wheat (*Triticum aestivum* L.), durum wheat *(T. durum* L.), rye (*Secale cereale* L.), oats (*Avena sativa* L.) and triticale (× *Triticosecale*). Of these species, Triticale is the youngest. It is a manmade hybrid between wheat and rye and was not commercially available until the twentieth century. Barley is undoubtedly the oldest cereal species in cultivation in Northern Europe and was the most important one during the early days of cereal cultivation. Of all the cereals grown in northern part of Europe, barley is the hardiest since it is least demanding in its weather requirements. No other cereal species is able mature grain under such short and cold growing season, that are common in the most northerly farming regions of Europe. Therefore, barley will be the main focus of this report which is aimed at the Northern periphery and Atlantic region.

Most of the barley grown in this region is used for animal feed. However, a small portion is grown for human consumption, either for baking , brewing or distilling. Potentially, barley could become a value product for farmers if the harvest could be used for human consumption. Wheat is the dominant cereal that is grown for human consumption in Europe. However, growing wheat in the Northern Atlantic region in a challenge, since spring types require about four additional weeks of summer in order to mature, in comparison to early maturing spring barley varieties. Winter wheat has greater potential in the region, since it uses the short growing season more efficiently. However, winterkill can be a big problem for growing winter cereals in many regions due to unstable weather and insufficient snow cover. Oats can produce mature grain in a shorter growing season than spring wheat. Furthermore, they do not attract birds such as geese and swans and therefore can be useful to protect barley fields against bird damages. Rye is mainly cultivated for human consumption and its cultivation tends to be small scale compared to the previously mentioned cereal species.

1.2. Winter - and spring cereals

Most cereal species have both winter - and spring types. In practice, the difference between the two types lies in the timing of planting. Spring cultivars are sown early in the growing season and harvested at the end of the growing season. Winter types are sown around the middle or end of the growing season. The plants are usually able to grow up to a four-leaf stage and are therefore green when winter arrives. The plants remain green throughout winter and start growing again in the spring. It is necessary for winter cereals to experience a cold period, otherwise they are not able to flower and produce mature grain. This process is known as vernalisation, which is controlled by about three genes in cereal species.

Not all cereals have both winter – and spring types. Winter oats are not grown in the Northern Artic region (NAR), but are cultivated in more southerly latitudes. Few varieties of spring triticale and rye are available at the moment, andt none that are suitable for growing in the NAR. Both spring - and winter types of wheat are widely grown in Scandinavia and

Denmark, due to its winter hardiness. Winter barley requires milder winters and is therefore not suitable in the NAR. Traditionally in Europe, the cultivation of winter barley does not extend further north than southern part of Scandinavia and Denmark. Winter varieties are generally higher yielding, since they are able initiate growth very early in the growing season and therefore use it more efficiently. Winter barley and winter rye are probably the most suitable in those regions of the Northern Atlantic region which have relatively stable winters and reliable snow covers. Variety trials in Iceland have revealed that rye has quite good winter survival rates, even in the unstable winters that commonly occur in Iceland. It can both be used for grain production and as an early grazing crop for sheep during the lambing period. Winter survival of wheat is variable but has been proven acceptable during several winters.

2. The barley plant

2.1. Root

Barley plants form two types of roots: primary roots and crown roots. The primary root is the first one to emerge from the seed and grows straight down into the soil (see Figure 1). This root can reach up to 2 m depth and its main purpose is to collect water for the growing plant. However, the primary root is also able to absorb nutrients from the soil which is important, especially if fertilizer is drilled into the ground along with the seed (see section 7.3). Once the primary shoots start to emerge, the crown roots start to grow out from the stem. These roots branch out close to the surface.

Figure 1. A barley grain which has been treated with tetrazolium. Tetrazolium only colours living tissue and in the case of barley seeds, that is the plant embryo). The white substance above the plant embryo is endosperm.

2.2. Stem

Barley plants will emerge from soil after about 120 growing day degrees (GDD, ∑T > 0°C, where T is the average daily temperature) from sowing. In an average May in Iceland this means about three weeks after sowing, but will of course vary across the region. Initially, only a single leaf emerges from the soil. Soon after, three more leaves appear. The plant growth stalls for some time at the four-leaf stage, which usually occurs after about 240 GDD from sowing. During the next growth phase, known as tillering, barley plants produce additional shoots. Each plant produces up to three additional shoots. However, experiments have shown that in Iceland the average number of tillers are close to two for 2-rowed varieties and only ½ a tiller for six-rowed varieties. These numbers are likely to vary between environments and cultivars. The number of tillers that are formed will greatly influence the yield potential of a field, since each tiller can form a flower head that will later mature into grains. It is therefore very important that barley plants at this stage have access to sufficient access to nutrients and water, since these environmental factors will greatly contribute to yield of the barley field.

Figure 2. Barley shoots starting to increase in height.

Figure 2 shows how the first tiller emerges. In addition to previously mentioned nutritional factors, light also influences the formation of tillers in barley. This means that when a field was sown at insufficient density, the barley is able to partially compensate by forming additional tillers. However, late tillering can cause problems. If the tillering occurs close to time of harvest, it will result in an uneven maturation of the field and the additional green material will cause problems for combines during harvesting.

In Iceland, stems of the barley plant start to elongate roughly eight weeks after sowing. The head emerges after about 10 weeks, in early maturing varieties, and shortly after the plant reaches its full height. In this report, we define early maturing barley as varieties that are able to fully mature after about 1,300 GDD or about 140 days with 9,5°C average temperature. The time that it takes the barley plant to reach previously mentioned developmental stages is of course highly dependent on temperature, where warmer climates will shorten this time.

2.3. Head

Barley is a predominantly self-fertilizing plant and the flower matures and gets fertilized before it opens. There are two main head types of barley: Two-rowed and six-rowed (see Figure 3). All barley forms six rows of florets on its flower head, but only two of these rows develop in two-rowed varieties. The difference in row type is controlled only by two separate genes and therefore the different row types are easily intercrossable. Crossing of these two barley types have been extensively utilized in the Icelandic barley breeding program.

Figure 3. Two-rowed barley on the left (IsKria) and six-rowed on the right (Icelandic breeding line).

The grains of six-rowed varieties are uneven in size and have an average of 45 grains per head, compared to 20 in two-rowed varieties. Despite higher number of seeds, six-rowed varieties are not always higher yielding. The grain size is larger in two-rowed barley and they tend to produces more tillers per plant compared to six-rowed varieties. Breeding of early six-rowed varieties with adequate yield has been more successful than in two-rowed barley. This means that the six-row type is more commonly grown in northern parts of Scandinavia. Cultivation of two-rowed varieties becomes dominant in the southern part of Scandinavia, since they tend to out-perform six-rowed varieties in longer growing seasons and warmer temperatures.

3. Barley in the field

3.1. Seeding density

The recommended seeding density for spring barley is about 200 kg per hectare. Unpublished experiments done at the Agricultural University of Iceland have demonstrated that higher seeding density does not lead to increased yields. The expected germination of seeds in the field is roughly 80%. An average thousand grain weight (TGW) of imported barley seed is roughly 40 and 45 grams for six- and two-rowed varieties respectively. That means that one expects to achieve plant density of about 400 plants/m^2 for six-rowed barley and 350 plants/m^2 for two-rowed varieties. Tillering of barley is dependent on several factors (as discussed in section 2.2) but on average six-rowed varieties in Iceland develop 0.5 tillers per plant whereas two-rowed varieties have on average two tillers per plant. This means that the number of heads range from about 600 – 1.000 per m^2. It is likely that tillering compensates for variability in seeding densities, especially due to the fact that the number of tillers is highly dependent on the availability of light at the soil surface.

3.2. Yield and its components

The yield of a barley field is comprised of four components: 1) Number of plants per unit area, 2) number of heads and tillers per plant, 3) number of grains per head and 4) weight of each grain. Component 1 and 2 were discussed in the previous section, and they are greatly influenced by environmental factors since unfavourable conditions at time of seeding or tillering can cause a reduction in the number of plants and/or tillers per unit area. Number of grains per head is a character which is greatly influenced by genetic factors and differs among varieties. Environmental factors also play a crucial role, since the floret primordia are formed at the tillering stage. The size of grains is under genetic control, two-rowed varieties have larger grains on average than six-rowed but also vary greatly within row-types. For example, the Icelandic variety IsKria tends to have much smaller grains than other two-rowed varieties. Despite these strong genetic influences, several environmental factors can stop grains from reaching full size. The most prominent factors are both related to water availability. Thus, drought during the growing season can cause plants to develop smaller grains than normal and frost during grain maturity has similar effects, since it stops grain filling.

During optimal growing conditions, the barley plant will continue to transport starch and other nutrients to the grains until they are filled. During grain maturation, stem and leaves start to yellow from the bottom up. Later in the process the upper part of the stems starts yellowing and lastly the grain itself (see Figure 4).

Figure 4. Barley transporting nutrients to seeds. The stem yellows from both ends, starting at the bottom.

Once this process is finished the dry matter (DM) is close to 60% and during that stage the seeds have reached physiological maturity. The next step in the process is ripening, where the seeds lose moisture and the DM % increases. The vascular tissue of the seed lose connection with the head and the seed slowly start to dry out. The optimal moisture content at harvest is close to 20%, but is seldom reached in the Norther Atlantic Region due to high precipitation which commonly occurs around the time of harvest (September and October).

4. Weather factors and barley cultivation

4.1. Heat requirements of barley

One of the most useful ways to estimate heat requirements for crops is to use so-called growing degree days (GDD). Growing degree days can be easily calculated by multiplyingthe daily average temperature of the growing by the number of days in the growing season (the number of days between sowing and harvesting). However, in this case the base temperature for calculating degree is 0°C. Other base temperatures are sometimes used, in which case the calculation is slightly more complicated. .

Unpublished results from the Agricultural University of Iceland have demonstrated that, in Iceland, the earliest maturing varieties of barley require roughly 1,300 GDD to mature. Later maturing barley varieties require about 1,400 - 1,500 GDD. Compared to other cereals, barley has the lowest heat requirements. Spring oats require about 1,400 GDD and spring wheat about 1,600 GDD. Despite these heat requirements, early maturing barley varieties can still be harvested at around 1,150 GDD and of course cut earlier for silage. But these earlier harvests will negatively impact yield. As mentioned above, early varieties require about 100 fewer degree days compared to later maturing varieties. This difference is also reflected in the time of flowering, where early varieties flower around 650 GDD but the later varieties do not flower until about 750 GDD. After flowering, the barley needs about 500 – 650 GDD to mature. In Iceland, a rule of thumb is that if barley has not flowered at the beginning of August, the best option for a farmer is to cut it green and use for green fodder.

Soil types also influence the heat requirement of barley. In Iceland, it has been observed that barley growing in sandy soils have less heat requirements compared to other soil types. The reason for this is thought to be that sandier soils have little water holding capacity and are therefore more easily heated up at the beginning of the growing season. Barley growing in sandy soils require about 100 fewer GDD compare to other soil types.

4.2. Water requirements of barley

It has been estimated that barley cultivated in Iceland requires about 4,000 tons of water per hectare during the growing season. This has both been estimated, based on plant physiology, and observed in multiple field trials for the past 30 years. The water requirement is however based on the expected yield of the barley field and the estimate reported above is based on an average yield of about 4 tons of 100% dry barley per hectare. Higher yielding varieties will require more water during the growing season. 4,000 tons per hectare translates into about 400 litres per m^2 or about 400 mm precipitation. However, barley has a deep root system and is highly efficient in taking up water from the soil. Many studies have been done on the water holding capacities of Icelandic soils. Dried wetlands and heathlands in Iceland hold about 400 mm of accessible water. This means that barley growing in these soil type is able to grow despite very little rain during the summer. Sandier soils types have much less water holding capacities, perhaps around 100 mm, which means that barley is dependent on rain during the growing season. Figure 5 shows this nicely. In 2007, it only rained 50 mm in 60 days in Reykjavík, where Korpa experimental station is located, from the 10^{th} June to 9^{th} August. Barley growing in deep heathland soils (bottom left corner of Figure 5) was not affected by this little rain. However, there is a region in the field where soils are quite sandy and barley experienced severe drought stress. This region is represented by a yellow patch in the field. This means that if the water holding capacity of soils is sufficient (around 400 mm) there is very little risk for barley to experience drought stress or damage.

Figure 5. Barley trial in a dry summer in Iceland. Drought damage only occurred where the soil was shallow. Barley growing in deeper (bottom left corner) soils was not affected.

5. Preparation of fields and planting

5.1. Types of soils

In Iceland, there are three main land types that are suitable for barley cultivation: heathlands, drained wetlands and sandy areas. Of these three, soils in heathlands are probably the most suitable for barley cultivation. It can be quite fertile and becomes ready for planting relatively early. Heavier soils, such as those in dried up wetlands, can also be suitable. However, the pH can be too low and barley is sensitive to pH levels below 5.2 (see section 7.1). Therefore, it is important to measure the pH in the field before planting and take action if the soil turns out to be too acidic. As discussed before, barley on heavier soils requires additional growing degree days to mature, compared to lighter soils. It is however not advisable to plant barley in pure – or close to pure sand. These soil types require heavy fertilizer inputs and the barley is vulnerable to drought damages, due to the low water holding capacity of the soil.

5.2. Preparation of soil

It is necessary to plough land that is taken under barley cultivation for the first time. Care must be taken that the former vegetation is sufficiently turned over, to ensure that the barley can grow in the absence of competition. The timing of ploughing is dependent on soil types and area. For example, soils in Iceland are very prone to erosion due to physical – and weather factors. This means that ploughing in autumn is not recommended. In an average field in Iceland, it is sufficient to prepare the seedbed by simply breaking down the soil ridges, left by the plough, using a harrow or similar machinery. After harrowing, the seedbed is ready for planting, in most cases. It is imperative to start preparing the soil for planting as soon as possible. If planting is delayed the soil can lose moisture and precious growing time for the young plants is lost. However, preparation should not be done too early and the soil should be free from any unbound water. Ploughing of wet fields can result in damages to the soil structure and impair aeration.

5.3. Planting

Planting should be done as early as possible, to ensure that the barley is able to use the entire growing season, which can be short in the Northern Atlantic region. The moisture level of the soil is a critical factor for deciding the timing of sowing. The following rule of thumb can be used to evaluate the moisture level of the soil: Take a handful of soil and squeeze it. If the soil forms clumps and water drips from it, the ground is to wet to prepare. If the soil does not form clumps when squeezed, it has dried out sufficiently and prepearation and planting should be started. Furthermore, it is imperative to finish soil preparation once started in as a short time period as possible. This means preforming ploughing and harrowing with as short time intervals as possible since this ensures preservation of precious moisture in the seedbed. The risk of night frosts must be taken into account when the timing of planting is decided. The seed tolerates mild frost around the time of germination. The first leaf of the plant is sensitive to frost and it is therefore important to minimize the risk that barley plants suffer frost during the first leaf stage of their development. Figure 6 demonstrates the benefits of early planting. The recommended seed rate is 200 kg/hectare and appropriate seeding depth is 2 -3 cm. If seeds are planted deeper it will result in slower seedling emergence. Planting seeds at shallower depths will increase the risk of drought stress for seedlings.

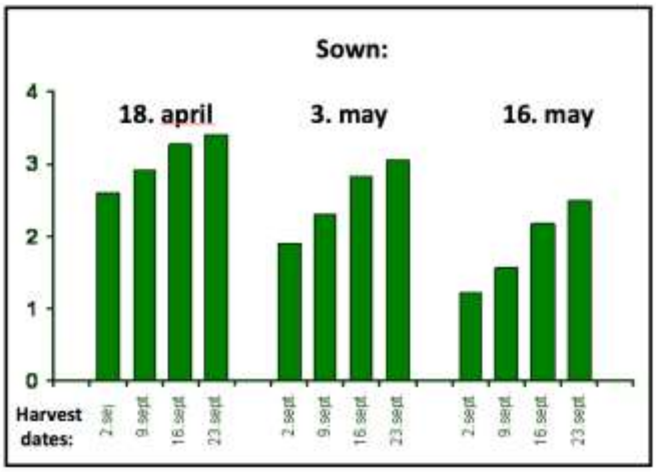

Figure 6. Effects of seeding- and harvesting time on the yield of barley in Iceland (three-year average). Planting and harvesting was executed with a difference of 60 GDD.

6. Seed and choosing varieties

6.1. Choosing varieties by region and soil type

One of the most important factors in the successful cultivation of barley, is choosing the appropriate variety. Several institutes and companies specialize in breeding early maturing barley varieties (see Table 1). Furthermore, it is imperative to follow the results from annual variety trials, that are performed throughout the Northern Atlantic region. It is difficult to recommend any varieties in particular since many of them have a relatively short commercial life, i.e. do not stay on the seed market for many years.

Table 1. Plant breeding companies or institutes that specialize in breeding barley for the Northern Atlantic region.

Company / Institute	Country	Website
Agricultural University of Iceland (AUI)	Iceland	http://www.swseed.com/*
Graminor	Norway	http://www.graminor.no/home-en-us/
Lantmännen	Sweden	http://lantmannen.com/en/
Boreal	Finland	http://www.boreal.fi/en/

*SW Seed handles seed distribution of AUI's varieties outside of Iceland.

It is most common to grow six-rowed varieties in regions where the length of the growing season is a limiting factor for barley cultivation. Breeding of early maturing six-rowed varieties has been more successful compared to early maturing two-rowed barley. Nevertheless, the growing of early six-rowed barley has been problematic in some regions, especially in the Southern part of Iceland. The reason for this is unclear, but tolerance of the straw to stormy autumn weather is one factor. The barley breeding program at the Agricultural University of Iceland has successfully bred weather tolerant varieties of two- and six-rowed barley that perform well and deliver stable yields. The complex interaction between genotypes (i.e. barley varieties) and environment are quite unpredictable and need to be tested in each region by conducting field trials. Therefore, it is not possible in this handbook to recommend any particular varieties for the entire Northern Atlantic region.

7. Fertilizer requirements for barley

7.1. Soil pH requirements

Barley is sensitive to soils with low pH and it is therefore advisable for farmers to have the pH measured in potential fields. The effects of soil pH on barley has been extensively studied in Iceland. Based on pH measurements of 150 barley fields, it was noticed that barley growth was severely negatively impacted by a soil pH below 4.9. The plants did not reach full height and had very limited tillering. Barley growing in soils with a pH ranging from 4.9 – 5.2

occasionally showed symptoms of growing in soil with low pH. Finally, barley growing in a soil with pH ranging from 5.3 – 6.8 was never observed to suffer from low soil pH.

7.2. Fertilizer requirements for barley

The soil type and chemistry of a field is the most important factor in estimating fertilizer requirements for a given barley field. It has been estimated in Iceland that, on average, a barley field removes 20 kg of nitrogen (N), 4 kg of phosphorous (P) and 13 kg of potassium (K) from the soil per ton of 100% dry grain. Estimating optimal nitrogen levels is the most critical step in this process. It is imperative that the barley plants have access to nutrients during early stages of development, since optimal levels of N, P and K ensures tillering. Excessive nitrogen levels later in the growing season is likely to delay the maturation of the grain and cause lodging. Furthermore, it can promote the production of tillers late in the growing season which will not be able to mature grain and will only increase the water content of the final harvest. Farmers should therefore aim to optimize nitrogen levels in a way that maximizes that yield without causing a delay in maturation of the grain. Specific fertilizer requirements will vary between locations and soil types across the Northern Atlantic region. Therefore, any specific recommendations require local fertilizer trials.

7.3. Combined drilling of seeds and fertilizer

In Iceland, there has been very positive experience with simultaneously drilling seeds and the fertilizer into the seedbed at the same time (see Figure 7). Furthermore, results from experiments conducted by the Agricultural University of Iceland have demonstrated that all of the required fertilizer should be drilled along with the seed. This fertilizer technique has delivered yield increases up to 23% in field trials. These results are contradictory to recommendations from other barley growing regions, where farmers are often warned against putting large quantities of fertilizer along with the seeds into the ground. This difference is thought to be due to differences in soil temperature at the beginning of the growing season, as it is relatively low in Iceland when the barley seeds germinate and plants start growing. Barley plants are likely to respond differently to fertilizer at these low temperatures that are common at the beginning of the growing season. It is therefore clear that potential benefits of drilling fertilizer along with seeds needs to be tested across the Northern Atlantic region.

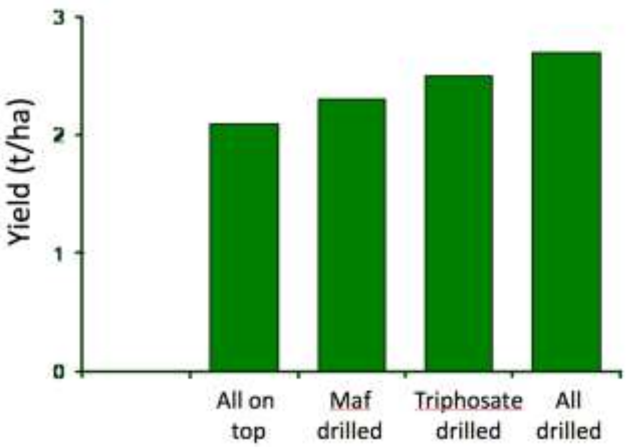

Figure 7. Effects of drilling fertilizer with barley seeds in Iceland. Large differences in yield were observed between treatments. An increase of 23% was observed with drilling all required fertilizer along with the seeds compared with applying it to the top of the field after planting. The two columns in between show the effects of drilling two types of phosphate rich fertilizer along with the seeds.

8. Grain maturity

8.1. Maturity period of barley

Grain filling can be regarded as a linear process from the third to the tenth week after flowering. The grain filling period is roughly seven weeks or about 50 days under the Icelandic climate. Then the kernels are fully mature (yellow colour) and dry matter is about 55%. After this step, the kernels will not add nutrients, only lose moisture. The moisture content of the kernels are determined by weather, particularly wind. Fully mature kernels contain slightly above 80% dry matter. Grain in Iceland seldom becomes fully mature.

8.2. Premature maturity; drought and frost

Maturity development of the kernels can stop due to environmental conditions. The kernels will then get dry and shriveled and will respond as fully developed grain. The stem can dry up during lengthy dry periods on gravel bed or dry land. If this happens soon after flowering the kernels become very small or even empty husks. Frost can also have the same effects and if it kills the embryo in fully mature kernels, then the germination capacity will be lost although the damage is not visible externally. The frost sensitivity of grain is variable. At the flowering stage, grain is particularly sensitive. As the grain matures, the grain becomes less sensitive to frost but it is difficult to predict how much frost can be tolerated at different stages. It seems that wet grain is more sensitive to frost than dry grain. Lastly, wind should be considered. Often it looks like development of grain stops and moisture loss starts after a heavy storm. Sometimes limited maturity of grain in Iceland could be related to storm effects.

8.3. Grain harvesting before full maturity is reached

In Iceland, it has been estimated that early maturing barley varieties need about 45 days after flowering to be suitable for harvesting. At the beginning of August, it can be predicted if full maturity of grain is likely or not. If maturity is not likely, it is advisable to harvest for feed. Then the fields should be harvested quite early since feed quality of the whole barley plants decreases with time. The weather conditions in Iceland often stop grain maturity development before full maturity has been reached. The specific weight of fully mature dried Icelandic barley is about 600-650 kg/m^3. Under the best conditions in Iceland fully mature barley is harvested but specific gravity is often lower than the 600-650 kg/m^3. For 30 samples in the period 2004-2008 from Northeast Iceland the specific gravity was reported in the range 370-670 kg/m^3.

9. Harvesting

9.1. Threshing

In late August barley fields in Iceland turn yellow and harvesting can start. Grain with more than 80% dry matter are most easily harvested. In Iceland barley is usually not harvested fully mature. Harvesting is a complicated process and the thresher should be adjusted for maximum output and minimum loss and damage to the grain. In Iceland, barley fields are usually cut and threshed by use of the same machine.

9.2. Tips on how best to tune combine harvester

Both driving speed and speed of rotation of the thresher are important and need adjustment. The speed of rotation of the thresher should be 1.3-1.4 times the driving speed. If driving speed is too high, grain can be lost from the thresher. Normal grain loss is estimated 3-5% of harvested grain. In Iceland grain loss has been found to be 0.8% to 12.6%.

9.3. Planning of threshing and optimizing the use of harvesters

Threshers are expensive and utilization is limited during the short harvesting period. It is recommended that farmers plan the threshing already before sowing in the spring. It is possible to sow both early and late barley varieties. The early varieties are harvested at the beginning of the harvesting period before the autumn storms. The late varieties will keep the grain better so later harvesting is possible. The weather is always a limiting factor and farmers have often few days for harvesting.

10.How to store the harvest

After combining the grain, processing starts. The grain is a living mass and this should be taken into account during processing and storage as for other feed. Kernels of grain respire as other living creatures and produce warmth. Molds and bacteria can reproduce in grain storages, particularly at high moisture levels. Two main processing methods are used for grain, drying and wet processing. Selection of a processing method should be based on the intended utilization. Drying is needed for grain to be used for seed, malt, feed concentrates or human consumption. Wet processed grain can be used as feed at the farm.

10.1. Drying

By grain drying the dry matter is increased to above 85% (less than 15% moisture). At this level of dry matter the grain can be stored for a long time. Grain drying is similar to drying of many other commodities. Heated air is used for drying of grain. The drying process is dependent on equipment, moisture content of grain, air temperature and how much heated air is used. Usually the heated air is blown through the grain mass. Different methods are used for moving the grain within the dryer to guaranty equal drying of all the grain.