Rit LbhÍ nr. 52

Research on Small Grains in Support of a Short-lived Renaissance in Cereal Production in Iceland in the 1960s and Its Recent Revival

Rannsóknir á korni til stuðnings við skammvinna endurreisn kornræktar á Íslandi á sjöunda áratugi 20. aldar og árangursrík endurlífgun þessarar búgreinar eftir 1990

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Cover photographs: Björn Sigurbjörnsson
Photographs: 1, 2, 4-17 from Björn Sigurbjörnsson
Photographs: 18-21 from Jónatan Hermannsson

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Summary

This report is part science and part history. It deals with research and farming activities in small grain production in Iceland half a century ago and its recent revival. It all started in 1960, increased swiftly over a few years and then disappeared, almost as swiftly, when the weather in Iceland took a turn for the worse with the arrival of – what some have called – a small ice age. It was not until the mid 1990s when grain production took wing again, coinciding with a trend towards more favourable growing conditions. In the early 1960s many farmers, a farmers´ cooperative and state and private companies started barley production on a fairly large-scale in many locations in Iceland but primarily in the south central part. Right from the beginning the Government of Iceland recognized the risk involved with grain growing in a country without grain cultivars adapted to local growing conditions. Thus, funds were made available to the Department of Agriculture of the University of Iceland Research Institute. It was given the task of testing foreign small grain cultivars and gene pools as well as to start a cereal breeding programme and associated research on fertilizer requirements and suitable cultivation techniques. This research went on for most of the 1960s until unfavourable summer weather made grain growing too risky. As all the cultivars tested during this period are now obsolete, no detailed and statistically analysed information on the performance of the different genotypes tested is presented. Research and breeding of grain, chiefly barley, did not take off again until the 1990s. Now, barley farming can be considered an established and successful agricultural industry in Iceland.

Útdráttur á íslensku

Skýrsla þessi er bæði vísindi og saga. Hún fjallar um rannsóknir og ræktun á korni á Íslandi á tímabilinu milli 1960 og 1970. Niðurstöður rannsóknanna voru aldrei gerðar upp og birtar í vísindatímaritum af því að vaxandi kuldaskeið á þessum áratug kom næstum í veg fyrir þroskun korns og frekari áhuga bænda á kornrækt og tengdum rannsóknum þangað til áratugum seinna. Í byrjun sjöunda áratugarins hófu margir bændur, samtök bænda, ríkis- og einkarekin fyrirtæki kornrækt, næstum engöngu byggrækt, aðallega á Suður- og Austurlandi. Stjórnvöld skynjuðu strax þennan áhuga bænda á kornrækt, en einnig þá áhættu sem bændur tækju með slíkri ræktun án þess að til væru yrki af byggi sem kynbætt höfðu verið fyrir íslenskar aðstæður eða erlend yrki sem gæfu nægjanlega uppskeru í íslenskri veðráttu. Þau veittu því rausnaleg framlög til Búnaðardeildar Atvinnudeildar háskólans til að stórauka leit og prófun á erlendum kornyrkjum og til kynbóta á byggi, ásamt auknum rannsóknum á áburðarnotkun og öðrum þáttum sem áhrif hafa á vöxt og þroska korns. Þessar rannsóknir hófust árið 1961 og var haldið áfram fram eftir þeim áratug þangað til kólnandi og versnandi veðurfar kom í veg fyrir kornþroskun. Þar með eyðilögðust allar kynbótalínur og sömuleiðis nær allir kornakrar bænda uns þeir misstu nær allir áhuga á frekari kornræktartilraunum. Þar sem öll kornyrki sem rannsökuð voru í þessum tilraunum eru ekki ræktuð lengur og allar kynbótalínur glötuðust er ekki að finna útreiknaðar niðurstöður um frammistöðu þessara yrkja og kynbótalína. Rannsóknir og kynbætur á byggi hófust ekki aftur fyrr en veðrátta á Íslandi fór batnandi um og eftir 1990. Nú má telja byggrækt meðal viðurkenndra og árangursríkra búgreina í íslenskum landbúnaði. Uppskera byggs á undanförnum árum er um tvisvar til þrisvar sinnum meiri á hektara en besti árangur í tilraunareitum og á ökrum bænda á sjötta áratug 20. aldar.

Background and early history

Iceland was settled in the late 9th century by a population immigrating from Scandinavia, the northern British Isles, Scotland and Ireland. Most of the settlers were farmers and their families. They brought with them seeds of small grains, primarily barley, from their former farms and planted them in Iceland. This is frequently reported in the Icelandic Sagas. Today, there are many names of farms and other place names which relate to grains – *korn* – in Icelandic, as in many other Germanic languages, and to grain fields – *akur or akrar* – in Icelandic. Grain growing was widely practiced in Scandinavia and the British Isles at the time of the settlement of Iceland. However, the highest summer temperatures in Iceland were about 4°C lower than in the countries of the settlers´ origin. Thus, the grain from the seeds they took with them did not develop as well in Iceland as on their farms in the old country, nor did they give anywhere near the harvest they would have expected. They must certainly have been disappointed with the performance of these seeds and the size of the harvest. Finding home grown barley seeds for planting must have been difficult as grain grown in Iceland rarely reached sufficient degree of maturity to allow them to produce seeds which germinated and developed into a new crop.

Accounts in the Icelandic Sagas indicate that grain, almost exclusively barley, continued to be grown until the 14th century. Grain production gradually decreased, most likely because of deteriorating climate making viable seeds unavailable for reseeding grain fields and general poor performance of barley, even if seed grain may have been secured from overseas (Jónatan Hermannsson, 1993). No grain varieties from this period exist now. The old primitive varieties of barley, Tampar and Sigur from the Faroe Islands, may be the closest relatives of the barley varieties cultivated in the first half millennium after Iceland was settled. These varieties are still grown experimentally in Iceland and have provided genetic material for the highly successful barley breeding programme carried out since 1990 and led by Jónatan Hermannsson. They are being maintained by the Nordic Genetic Resource Centre.

Figure 1. Klemenz Kr. Kristjansson and Jan d´Fontaine in barley field at Hvolsvellir 1962.

Figure 2. Björn Sigurbjörnsson inspecting a barley trial on sand at Gunnarsholt in 1963.

Archaeological studies made by Sturla Fridriksson have revealed well developed barley grains in Iceland from the 11th century. Other discoveries of barley grains from the 14th century show poorly ripened seeds. In the mid-18th

century Norwegian and Danish farmers came to Iceland to cultivate barley and teach farmers how to grow barley. They were not successful. Later in the same century two Icelanders were sent abroad to learn grain farming, also without success, probably due to the very cold climatic conditions in Iceland during most of the 18th century.

It was not until Klemenz Kr. Kristjánsson, who headed the Sámsstaðir State Experimental Station in south central Iceland, started to experiment with barley cultivation in the 1920s that grain production slowly attracted interest in Iceland. Klemenz was an agronomist by training and carried out comparative studies of introduced barley varieties as well as studies on fertilizer applications, tilling methods and methods of planting seeds. He thus laid the foundation for grain growing in Iceland in the 20th century. He was not a breeder and did not attempt any cross-breeding. Following his fairly successful experience with barley cultivation, other farmers in south and east Iceland began to grow barley on a small scale in the 1950s. After a small improvement in summer temperatures, especially in 1960, a brief renaissance in grain production started and grew rapidly for a few years only to be stifled quickly again by worsening growing conditions towards the end of that decade with the arrival of a small „ice age“. It put an end to almost all further attempts at small grain production as well as to the budding research and breeding efforts which had been started by the University of Iceland Research Institute in 1961. Towards the end of the decade none of the breeding material survived long enough to produce viable seeds and widespread harvest failures discouraged almost all farmers from further attempts at grain growing. Further research efforts also became pointless. Thus, at the time there was little interest in completing the data analysis and publishing the results of the research as a scientific paper. During the span of the research activities, however, reports on the experimental findings were made available to farmers in lectures, farmers´ publications and newspapers, most of which, plus most of the original research data, still exist. This material forms the basis for this report. Barley cultivation was continued on only two farms, the same ones that did so before the „renaissance“. One of them, the farm Thorvaldseyri in south Iceland, is today arguably the most successful grain growing farm in Iceland.

The weather factor

The climate in Iceland is predominantly influenced by the far north geographic location of the country, touching the Arctic Circle, although the warm Gulf Stream, together with the abundant daylight in the summer, makes the island more inhabitable. The decisive factors for successful grain farming in Iceland are summer temperatures, cloud cover and the length of the growing season. This means the arrival of spring at the end of April or beginning of May and the first incidences of early autumn frosts or stormy and wet weather during harvest in September and October. Available accounts on weather conditions from the time of settlement, together with data from the Icelandic Meteorological Office, indicate clearly that temperatures at the time of settlement and during the following 500 years were significantly higher than those prevailing during the Middle Ages into the 20th century (Sigurður Thórarinsson, 1974). The highest summer temperatures in the 20th century have also varied considerably and the good results in barley cultivation at Sámsstaðir State Experimental Station coincided for example with favourable periods (Figure 3). Better weather in the late 1950s and especially in 1960, together with the fairly successful barley cultivation by a few farmers in east and south Iceland, seems to have been the main stimulus for the surprisingly great interest in grain growing and the willingness to take risks by farmers and others in greatly expanding grain acreage at that time. As one can read in newspaper articles and other published material from this time there were high expectations and even greater hopes for a brighter grain future in Iceland. It is also quite clear that the rapidly decreasing temperatures after 1960 explain why this renaissance was so short

lived (Figure 3). Poorer growing conditions in the 1960s were not only due to the decreasing summer temperatures but also to late springs and the early autumn frosts and storms.

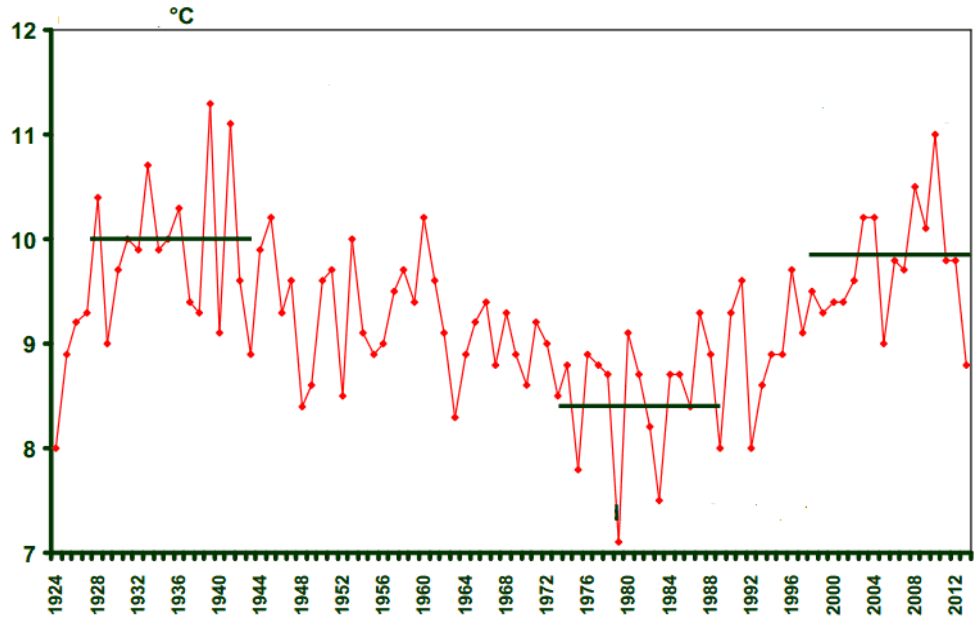

Figure 3. Mean summer temperature (May-September) in Reykjavik 1924-2013 (red line) and means for the warmest 14 years 1928-41 (10.02°C), coldest 14 years 1979-86 (8.42°C) and the last 14 years 2000-2013 (9.79°C) (provided by Jónatan Hermannsson, based on data from the Icelandic Meteorological Office).

As will be discussed later the successful grain cultivation in the years after 1990 clearly coincided with higher summer temperatures, although the highly significant, if not outstanding advances in barley breeding in Iceland in the 1990s are as important if not the crucial factor for this remarkable success.

The small grain boom of the 1960s

The summer of 1960 had many warm and sunny days. The author, having returned that spring from many years of studies abroad, was quite impressed with the rapid maturity of grain and grass seeds allowing for extensive collections of seeds of different types of pasture, hay and crop plants. This included imported brome grass (*Bromus inermis*) from North America, which did not bear viable seeds before 1960 or for many years after. The Icelandic Government, the Agricultural Society of Iceland, some private commercial firms and a number of farmers were stimulated by these favourable conditions and the recent success of some farmers to start large-scale grain production with the perhaps understandable hope and expectation that the year 1960 signalled the beginning of favourable growing conditions in Iceland for years to come.

The Union of Icelandic Cooperatives (SIS) established large barley fields near Hvolsvöllur in south Iceland. Some private companies, e.g. the firm Hafrafell, also had large barley fields near the farm Gunnarsholt, the site of the Headquarters of the Soil Conservation Service. Gunnarsholt became the main site of the small grain research programme which started in 1961. In north east Iceland a large barley project was started in Suður-Thingeyjarsýsla, near the waterfall Goðafoss, by an Icelander, Bjarni Pétursson, who had just returned after several years of running a grain and beef farming operation in Colorado, U.S.A. He decided to use his experience and knowhow to set up Colorado-style farming in this area. The farmers formed a cooperative and ploughed about 100 ha of land,

Figure 4. Farmers Sigfús Jónsson and Bjarni Pétursson, and Skapti Stefánsson advisor, in a barley field, Einarsstadir, S-Thing. 1962.

Figure 5. Seeding a barley field in the sand "soil" at Gunnarsholt 1962.

bought all the necessary equipment for small grain growing, including a combine and a drier to produce feed grain for their livestock. The author drew up the plans for them, ordered barley seed of the varieties thought to be best adapted to the area and the seeds were planted in the spring of 1962. The Minister of Agriculture at the time, Mr. Ingolfur Jónsson, stated in the Althing that grain growing in Iceland was still a risky business and without extensive research work, primarily to develop better adapted grain varieties, it would not become a dependable farming enterprise in Iceland. This was most unusual for a politician to say in any country. In 1960 the Government had established the firm Feed and Seed at Gunnarsholt with the task of producing grass pellets, forage grass seeds and barley on eroded land reclaimed by the Soil Conservation Service. The firm purchased seeding equipment, combines and a grain drier. The Government also provided funds to the University of Iceland for starting the research and breeding activities. The Minister appointed the present author to organize and lead this research which expanded rapidly in the early 1960s.

In 1960 there were about 50 ha of barley in Iceland. In 1961, the acreage had grown tenfold to some 500 ha with yields of 1.6 – 2.0 t ha^{-1}, giving about 800 to 2000 tons of dry grain (15% moisture). There were also some 200 ha of oats. It was reported on the radio that some farmers got up to 3 t ha^{-1} in 1961. Of this acreage about 300 ha were owned by state and private firms, all near Gunnarsholt in south Iceland. Although growing conditions for small grain growing were not considered optimal and the harvest season bad, the growers were in general not too unhappy with the outcome and the plans for 1962 were on a larger scale and many more farmers joined. The following parameters were recorded for the growing of barley at Gunnarsholt in 1961: the seed rate was 130-170 kg ha^{-1}, the recommended fertilizer rates for sandy soils were 115 kg of N, 40 kg of P (P_2O_5, triple phosphate) and 50 kg of K (K_2O potassium) ha^{-1}. For loam soils the recommendations were: 43-56 kg N (higher N applications had been shown to delay ripening), 40 kg P and 50 kg K ha^{-1}. The time of seeding and fertilizer application was in general between 2 and 20 May. The first trial was harvested on 7 September and harvest was completed on 7 October. The moisture content of the grain at harvest was 40-50%. It was then dried in oil driers down to 15% moisture for storage (personal records from

1961). In 1962 the barley acreage reached some 1200 ha but the growing conditions had continued to deteriorate leading to a rapid decrease in barley acreage in the following years.

The climate turns to the worse

The weather Gods, on the other hand, did not share this enthusiasm and turned the climate in another direction (Table 1). Scanning the correspondence the author had with his colleagues and co-workers at the time, one can discern the disappointment and gloom that the rapidly worsening climatic conditions were having on this budding enterprise: the strive towards self-sufficiency in feed grain production. After 1963 the research activities gradually slowed down along with the deterioration in growing conditions and decreasing barley yields towards the end of the decade when barley was only grown on two farms in south Iceland. The farmer, Eggert Ólafsson, on one of these two farms, Thorvaldseyri, reported later that all through these bad years he was able to obtain acceptable harvests up to 2 t ha^{-1}.

Table 1. Mean summer temperatures (°C) at five locations in Iceland, 1931-1965 (from Jónas Jónsson, 1966).

Location	1931-60	1960	1961	1962	1963	1964	1965
Sámsstaðir	9.60	10.50	9.70	9.18	8.64	8.84	9.20
Reykjavík	9.40	10.20	9.57	9.10	8.22	8.88	9.22
Akureyri	8.92	9.38	9.10	8.38	7.40	8.06	7.76
Hornafjörður	9.06	9.58	9.58	8.54	8.38	8.68	7.54
Vík í Mýrdal	9.54	9.98	9.98	9.28	9.00	8.86	n.a.

The drop in temperatures in the early 1960s did not only affect Iceland; it seemed to have affected agriculture in many countries in northern Europe. In 1962 it was not possible to obtain barley seed from the Norwegian co-operator, M. Bjaanes, because of harvest failures. Similarly Erkki Kiwi, the Head of the Hankkija Experimental Farm at Tammisto, Finland, wrote to say that they were unable to provide seeds of barley, wheat and oats because of crop failures in 1962 and, indeed, had to import seeds themselves. Klemenz Kr. Kristjánsson, head of Sámsstaðir State Experimental Station, wrote about the conditions for grain growing in Iceland in 1963: „The summer of 1963 was unsuitable for potato and grain growing. It was not the spring that caused it but the latter part of the summer. In July the mean temperature was 1.3°C below average. There was one night below freezing and many cold nights. August was 1°C below average with 8 cold and frosty nights. September was 1°C below average with 10 cold and frosty nights before 23 September. Such a bad season has not occurred in the 38 summers I have operated this station, although the summers of 1937 and 1940 were similar but not as bad as this summer." The great enthusiasm accompanying the start-up of large-scale barley production in Iceland in the early 1960s aroused the public and the press to closely follow these developments. The press was especially interested in reporting the making of bread and cakes from the Norwegian wheat variety Norrøna, bred by Dr. M. Bjaanes, grown at Gunnarsholt in 1963, as well as in the accompanying research activities aimed at starting this enterprise on the right foot.

The return of barley cultivation

After 1965 the mean summer temperatures plunged eventually to 7.1°C in 1979 and 7.5°C in 1983 with some fluctuation from year to year. After 1984 the long-term average slowly rose until, in the early 1990s, it exceeded 9°C again. This led to a spurt in grain growing with average summer

temperatures starting to exceed 10°C coupled with excellent successs in hybridization and selection, resulting in superior barley lines. Grain growing in Iceland now has become fairly widespread with mean yields generally over 3t ha^{-1} and in some areas reaching 6-8 t ha^{-1}, on par with good results in Scandinavia. This was brought about by a major emphasis on breeding, but better knowledge of cultivation techniques and fertilizer use was already at hand from the barley field experiments conducted during the brief „renaissance“ period in the early 1960s.

A short look in the Farmers' Handbook

It is interesting to trace the history of grain growing in the 1960s through reports and advice on barley farming which were published in the Farmers´ Handbook (Handbók Bænda) for that period. In 1960 there was no special reference to grain production and all the emphasis was given to forage and horticultural production. In 1961, however, Klemenz Kr. Kristjánsson wrote a short chapter on cereal growing (pp. 128-130) followed by two chapters by the present author in 1962 (pp. 102-107) and 1963 (pp. 138-142). In 1964 there was no special reference to grain growing but three of the experimental stations reported that some trials were carried out, all with poor or no success due to bad weather. In 1965 there is no special entry on grain growing in the Handbook but two experimental stations in north and east Iceland carried out some variety comparisons with poor results. The Akureyri Station reported that the Farmers´ Barley Growing Cooperative, Öxará, in North-Thingeyjarsýsla, under the leadership of the former Colorado farmer Bjarni Pétursson, had decided to curtail their operations and that Akureyri was the only place in north Iceland that grew barley in 1964. In 1966 my successor, Jónas Jónsson, wrote in the Farmers´ Handbook a ten page review of grain growing for the six years 1960-1965. He reported the declining performance of small grain cultivars in this period but concluded that there were certain favourable areas in south, south-east and east Iceland where grain production could be recommended. His conclusion was that the low yields were due to the decline in mean summer temperatures for the period. He also made recommendations to farmers for the choice of varieties and fertilizer rates based on the results of the

Figure 6. Jónas Jónsson in an oat field at Gunnarsholt 1963.

Figure 7. Barley harvesting at Gunnarsholt 1962. Sveinn Runólfsson on tractor, right front.

field research. There was also an article in the same issue (p 229) where it was recommended that, instead of oil- fired drying, farmers should preserve harvested but immature grain as silage using special plastic containers or putting the grain in earth dugouts rather than attempt drying. The 1967 to 1973 issues did not contain any reference to grain growing but some of the experimental stations reported on minor trials and the poor results obtained. After 1970 the only reference to barley growing came from the Sámsstaðir Experimental Station where 5-10 ha of barley were grown each year with yields up to 1 t ha^{-1}.

Research support 1961-1963

For the various reasons discussed above, a number of farmers throughout Iceland decided that the seventh decade of the 20th century would see cereal growing developing into an important industry in Icelandic agriculture. After a half a millennium since the disappearance of grain fields from Icelandic farms a large scale effort would be launched. The main drawback, together with the unfavourable and unpredictable weather conditions, was the lack of suitable small grain varieties for Icelandic conditions as noted before. There were no locally bred varieties and only a few introduced varieties had been tested. Furthermore, due to the very different types of soils available for grain growing, consisting of drained bogs, dry loam soils and vast areas of eroded sand deserts, knowledge of suitable fertilizer rates, spacing and sowing times for these varied soil types was limited. Also very few farmers had much experience with soil cultivation and grain production as most of Icelandic agriculture was based on permanent hay fields and pastures.

The tasks ahead for the scientists were therefore rather clear-cut: Breed or find adapted varieties with emphasis on barley, determine suitable types and rates of fertilizer applications and optimal spacing of rows and of sowing times for the different soil and weather conditions in the country. Thus the winter of 1960-61 was spent establishing a research team, contacting sources for seeds of interesting varieties and ordering samples for testing, drawing up statistical designs for the various field experiments to be carried out on different soil types and in different parts of the country and weighing out the portions of seeds and fertilizers for each plot. Fortunately the extra funds provided from the state budget permitted the design of a rather comprehensive plan of experimentation. Most of the seed samples of small grain varieties and lines were obtained from the Scandinavian countries, the northern European continent, the UK and North America. Lines of barley, oats and wheat were also obtained from the Soviet Union and China. The breeding material was to come from targeted crosses of selected introduced varieties to the extent hybridization could be carried out in Iceland, which then did not have any greenhouse facilities available for research. Furthermore, the author made contacts with colleagues, mostly in Canada, the U.S.A. and Scandinavia to ask them to send segregating material from their own cross-breeding programmes as well as from their radiation-induced mutation programmes. Also we received seeds from the USDA, California, resulting from what was called composite crosses, consisting of segregating populations of 15 male-sterile female parents inter-seeded with numerous pollen providers. All this material was in various stages of advanced segregation from F_2 or M_2 to advanced F_{3-5} and M_{3-5} generations. All we had to do was to spot the winner! Little did we know at the beginning that very soon the deteriorating climatic conditions would not allow any of our selections to ripen sufficiently to give any germinable seeds, thus ruining our breeding efforts. The last record in the author´s possession of any breeding activity in this period is from 1965.

The staff and other persons associated with the research activities, in addition to the author, were my closest co-worker Gunnar Ólafsson, a graduate from Norway, later a PhD expert in animal nutrition

Figure 8. Harvesting barley trial 010-62 at Gunnarsholt. From left: Einar Erlendsson, Björn Sigurbjörnsson, Ólafur Ásgeirsson.

Figure 9. Seeding cereal trial at Gunnarsholt, 1962. Gunnar Ólafsson on tractor.

and my successor as Director of the Icelandic Agricultural Research Institute, RALA; Jónas Jónsson, also a graduate from Norway who took over as supervisor of the experimental work after my departure in 1963 (he later became Director of the Agricultural Society of Iceland); Ólafur Ásgeirsson, an agricultural graduate; Einar Erlendsson, an agronomist, who later became Head of the Korpa Experimental Station; Friðrik Pálmason, a graduate from Denmark who later became a PhD expert in plant nutrition at RALA; a number of agricultural advisers who operated the field trials all over the country and are named later and many others. Páll Sveinsson, the Director of the State Soil Conservation Service, Gunnarsholt, was extremely supportive of the research activities, making available the land under most of the experiments, all land preparations, fencing and fertilizers. More details on experimental activities during 1961 are given in Appendix.

The main conclusion from the Gunnarsholt trials on sand were that with 18 kg P ha^{-1}, increasing N from 90-130 kg ha^{-1} did not result in yield increases in barley. However, there was significant increase in yield by raising N fertilizer to 130kg ha^{-1} if P was also increased to 25 kg ha^{-1} . Raising both N and P increased yields on the eroded sands. The application of K had no effect on yield. There were also indications that increasing both N and P above 130/25 kg ha^{-1} might lead to higher yields on the eroded sands. All the 1961 data were statistically analysed. The replications were mostly 2-4 and the size of the plots generally $6m^2$. The statistical plans for four large experiments at Korpa and Gunnarsholt were completely randomized factorial, two were split plot factorial and two were randomized block with a control variety. One trial at Korpa was laid out as triple partially balanced lattice. The results were used in meetings with farmers and agricultural advisers and presented in articles on grain growing in the Farmers' Handbooks during this period. The intention was to analyse and prepare the field results for the first five years for publication in a scientific paper but after the collapse of grain growing in Iceland resulting from the deteriorating climate there did not appear to be any interest in preparing the results for publication in scientific journals.

The year 1961 had been acceptable to some grain farmers but almost a failure for others. There was still much interest and enthusiasm for the future of grain growing in Iceland. Certainly the weather

had to improve in 1962, at least this is what farmers believed – or hoped for. In 1962 the barley acreage increased from some 500 ha in 1961 to about 1500 ha. The researchers made big plans for 1962 with some 2400 plots, mainly at Gunnarsholt, Korpa and Skógasandur but also with local trials at the following locations: Vík in Mýrdal in the central south, Hornafjörður in the south-east, Egilsstaðir and elsewhere in Fljótsdalur, including the experimental station Skriðuklaustur in east Iceland, South Thingeyjarsýsla near Goðafoss in the north east; Barkarstaðir, Húnavatnssýsla in the north-west and Bæjarsveit near Hvanneyri Agricultural College in the south-west. The experiments were carried out on drained bogs, dry river beds, ploughed hayfields and on sandy soils and eroded sands.

Most of the experiments were carried out at Gunnarsholt, both on eroded sands and on cultivated hayfields. Three types of research were carried out: Breeding of barley, oats and wheat, comparisons of cultivars and lines, and fertilizer trials (for more details see Appendix). The threshing and cleaning of all plot harvests and the analyses of data were carried out at the Agriculture Department, University of Iceland Research Institute, Reykjavík. A number of some of the 2400 plots in 41 experiments carried out in 1962 gave no mature grains due to the very unfavourable summer weather conditions and severe late summer storms. Nevertheless, in some areas many of the cereal varieties reached maturity and yielded valuable information. A report on grain farming given by the author to agricultural advisers in the spring of 1963 concluded the following: „The new grain growing activities started in 1961 and we now have experience from two seasons. The results were acceptable in 1961 and poor in 1962. The summer of 1962 was difficult and not suitable for grain production. Spring seedings were late, the spring was cold, the summer acceptable but serious frosts in August and September stopped the ripening process and heavy storms in September delayed the harvest and caused damages in the fields. The worst experimental results were in north and north-east Iceland. Poor results in north-west and west Iceland and also in south Iceland as far east as Eyjafjöll, just east of Sámsstadir. From there east to Hornafjörður the results were acceptable, 2 t ha^{-1} or more“. The highest yields were measured at Hvammur, Langadal in the north west and at Teigingarlækur in the south east. On the eroded sands in south Iceland, the old Faroe variety Sigur had the highest yield,

Figure 10. Experiment 001-1961, comparing barley varieties at Gunnarsholt.

Figure 11. Barley field, variety Jøtun, with volcano Hekla in background 1961.

well over 2 t ha^{-1}. However, Sigur is so shattering resistant making threshing difficult. It is interesting to note that on the eroded sands, oats yielded most often twice that of barley. Wheat sown on 20 April yielded equal to barley but less than oats. However, wheat seeded 28 April gave hardly any harvest.

In 1962, data for analysis were available from four fertilizer experiments at Gunnarsholt and one at Skógasandur. There were six experiments comparing varieties of the three small grain species. Analysis of some of the experimental data was carried out by Professor Ovid Nissen, Institute for Plant Production, the Agricultural College of Norway. He did the statistical analysis on 70 varieties of barley for scores given for lodging, shattering and earliness. He also did statistical analysis on a fertilizer experiment with 40 barley varieties and two fertilizer treatments for scores given for the same parameters as above. There were no such analyses done for yields due to the poor development of the kernels in the 1962 growing season. The detailed results were never published but used in recommendations given in the Farmers' Handbook the following year and at meetings with farmers and agricultural advisers.

The growing conditions in 1962 were worst in north and east Iceland but can be described as very poor for the whole country. The agricultural adviser for east Iceland, Páll Sigbjörnsson, who carried out a trial with two barley varieties, wrote in October 1962: „the emergence of the plants was satisfactory but they were slow to develop due to the very cold weather. The land was very wet at the time of seeding which also caused some delays. On 16 September the frost reached -7°C which followed a few frosty nights. At that time the 6-row barley variety Edda was green and the barley variety Fløya was beginning to turn yellow. The frost that night caused Fløya to turn white, dry up and die. Edda seemed not much affected by the frost and continued to ripen. The Edda variety also suffered from shattering". The Norwegian wheat variety Norrøna from Dr. M. Bjaanes grown on 0.3 ha of eroded sand at Gunnarsholt, did quite well. The mature grain was harvested, threshed and ground. The flour was given to the Home Economics School in Reykjavík where the headmistress and teachers baked bread and various sorts of cakes, the first baked products from wheat grown in Iceland. This was quite a sensation and reported on extensively in the media at the time.

Figure 12. Edda barley field at Gunnarsholt 1962.

Figure 13. Wheat field, 0.3 ha, Gunnarsholt 1962. Norwegian cultivar Norrøna.

The very poor outcome from grain growing in Iceland in 1962 resulted

in less enthusiasm among growers, although many were still optimistic and believed in better times ahead. Thus, in 1963 there was considerable increase in grain growing in Iceland. Although somewhat discouraged, the research group worked out fairly extensive plans for the following summer. The meagre results obtained in 1962 were used to update advice to farmers, used in a few lectures, but the results were never published in a customary manner for scientific results, as interest in further grain growing by farmers quickly waned. The group still had hopes for the new selections they had made among the breeding lines, some of which looked very promising. None of the 70 introduced varieties of barley tested proved to be adapted to the growing conditions experienced in 1962. It is noteworthy that oats did considerably better than barley in the trials but for some reason growing oats for grain has never become popular by farmers, although oat cultivation for green fodder was widely practiced in Iceland (and oat porridge a popular dish, not only on farms). There was also little interest in wheat, in spite of the reasonable success attained.

The cereal research in 1963 started in a remarkable way. The winter had been mild and in March there was no frost in the ground in the eroded sand lands in south Iceland. The late-winter weather had been sunny for days with temperatures of 8-10°C. It was therefore decided to conduct trials comparing the effects of sowing time on grain maturity and yield at Skógasandur. Detailed plans were made with three sowing dates, on 12 March, 10 April and 13 May, using one variety each of barley, oats and seed rape. When it came to the 2nd planting date in April, the expedition reaching Skógasandur on 8 April found that the plants sown on 12 March had grown to 5 cm. The following day was spent seeding a few varietal testing and fertilizer experiments, the 2nd sowing date treatment being planned for 10 April. The team had erected two tents on the sand and had one station wagon loaded down with seeders, fertilizer spreaders, seed and fertilizer bags in addition to the four field staff. The day had been pleasant, blue skies and the temperature around 8°C. After a hard day's work, we sat in one of the tents around 7 pm to have dinner, when out of that blue sky, a violent storm slammed into the tents. We managed to get a hold of the tent we were in but the other tent, where the supplies and some equipment were stored, simply took off into the yonder.

Figure 14. Sowing time test on Skógasandur 8 April 1963. Tent base and Skógafoss in background right. –17° and orkan following day. Einar Erlendsson facing camera. Author´s Plymouth in background.

Figure 15. Harvesting a cereal trial at Gunnarsholt 1962.

We got out and sensed the ice-cold orkan being whipped up. We had great difficulty loading the car, but headed through the very cold and violent storm for the nearest farm where we stayed overnight. The morning after the temperature had dropped from +8°C to -17°C and the wind had blown away all the plantings from March and ruined a large part of the plantings we had just made, not to speak of the tent and supplies. This storm is still referred to as the storm that killed most of the poplar trees and Sitka spruces in Iceland, and also took the lives of a number of fishermen. The May sowing was carried out without incident. The yields of the surviving plants were poor or ranging from 0.12 to 1.45 t ha^{-1}. A detailed account of other experiments from 1963 can be found in Appendix.

End of the brief renaissance

In the fall of 1963, the author followed the migrant birds and moved from Iceland to warmer climes first on temporary leave so that he was in nominal charge of the grain experimental activities for the following two years. Jónas Jónsson took over the supervision of the research activities on grain and carried them out until they were terminated. The research activities in the following years were more or less along the same lines as described above. Emphasis was put on finding suitable introduced varieties and continuing the breeding programme through further selection and propagating promising breeding lines.

Farmers and agricultural advisers were still interested in doing local trials and observations. In the years 1962 and 1963 the climatic conditions had become progressively worse but 1964 turned out to be still worse as reported in the letter from Klemenz Kr. Kristjánsson cited above. It is interesting to note that in his letter he reports that in this cold summer of 1964, the radiation- mutant, the 2-row barley variety Mari, bred by Prof. Åke Gustafsson of Svalöf, Sweden, yielded 3.5 t ha^{-1} and a line of Dönnes barley yielded 3.2 t ha^{-1} at Sámsstaðir. Winter barley, seeded on 15 July 1963 and harvested fully ripe on 10 August 1964 yielded 3.5 t ha^{-1}. Klemenz was still doubtful about the suitability of winter barley for Iceland as it can only be harvested every second year due to the need for seeding in mid-summer the previous year. In 1964 Klemenz gave a short summary of his experience with grain growing in Iceland over the years where he states that at Sámsstaðir in 1928 – 1940, the barley varieties Dönnes, Maskin and Jøtun yielded on the average 1.82 t ha^{-1}. In 1961 the mean yield was 1.56 t ha^{-1}. The yield of oats, Nidar, Voll and Orion in 1928 – 1939 averaged at 2.3 t ha^{-1} while hay yields averaged at 4.53 t ha^{-1}. Turnip yields in 1932 to 1936 averaged over 30 t ha^{-1} and potatoes 23-32 t ha^{-1}.

The agricultural adviser in east Iceland, Páll Sigbjörnsson, wrote a summary of the 1963 experience: „Barley was seeded at 27 locations in east Iceland. The varieties used were the 6-row varieties Fløya and Sigur, and the 2-row varieties Union, Mari and Herta. The planting time was the latter half of May. In general the plants developed well into the summer. In September many farmers gave up all hope of getting a fully mature grain harvest and started to cut the fields for green fodder. Grain harvest started in mid-September with yields from 1.2 to 1.5 t ha^{-1}, and the grains were reasonably well mature. The main harvest started at the end of September and harvesting of the 6-row varieties was completed in mid-October. Many of the 2-row varieties were harvested later. The harvest was poor everywhere. The 6-row varieties yielded 1-1.2 t ha^{-1} and the 2-row varieties yielded 0.7-1.0 t ha^{-1}. All the 2-row varieties matured later than the 6-row varieties. The old hardy Faroe Islands variety Sigur did not ripen at all and was not harvested. Most of the varieties survived the severe frosts, especially the 2-row varieties although damaged. The spikes of some varieties reached full size but had no grains, probably due to frost damage during pollination.“ Then Páll states: „The previous two

Figure 16. Trial with barley lines and fertilizer rates on Skogasandur 1962.

Figure 17. Prof. Sigurdur Helgason, University of Manitoba with Thorsteinn Tomasson at Thorvaldseyri 1985.

summers have dampened the enthusiasm in farmers who are nevertheless still expected to continue on the same scale in 1964“.

In 1963-64 the author assisted in ordering barley and oat seeds from 27 seed firms and research institutes in the UK, Norway, Sweden, Finland, the Netherlands, Ontario and Manitoba, Canada and from Minnesota, U.S.A. In 1965 the trials were carried out nearly on the same scale as in 1964. On a visit to Iceland in 1966 the author visited some of the 21 cereal experiments carried out that year. Local trials were mostly carried out on the same farms and experimental stations as before, mostly barley, but also some oats. There were five large scale experiments at Gunnarsholt and three at Korpa. There is no mention of any activities at Skógasandur that year. The author has not been able to locate details for these activities, nor any reports on results.

In 1964, 1965 and 1966 Jónas Jónasson followed up on the breeding activities to the extent possible under the deteriorating growing conditions. In 1964 there was some material in the F_2 generation from which he made selections, establishing F_3 lines as spike progenies in 1965 both from the crossed material and from the progeny of the radiation-treated populations received from Canada and the composite crosses from California. The last were rather disappointing with very few interesting lines. These breeding lines were evaluated for date of emergence, height, straw strength and shattering resistance. Jónas had plans to establish progeny lines from each spike line in 1966 and make selections from these progenies. He then planned further hybridizations between the best selections in a rented greenhouse space. However, all this effort came to nothing after even all the reserve seed had been sown and then failed to give viable seeds due to the poor climatic conditions. Thus the brief grain growing renaissance starting in 1960 came to a much premature end due to the outset of the „little ice age“.

Epilogue – recent, present, future

Work on barley variety testing and cross breeding were started again at RALA in 1976 by Thorsteinn Tómasson and later followed up by Árni Bragason. The results of this work together with the later input by Jónatan Hermannsson led to the development of the superior barley varieties which are the main contributors to the high and staple yields now obtained by farmers in Iceland. In 1982 when the author was Director of RALA, he gave a talk at a technical meeting of the agricultural advisers in Iceland, including the following: „for half a century Klemenz Kr. Kristjánsson carried out experiments with small grains at the Sámsstaðir State Experimental Station and harvested fully ripe grains in 8 out of 10 years. The summer temperatures in the 1930s and early 1940s were generally more favourable, averaging at over 10°C, than in the 1960s and 1970s. Hardly any farmers grew small grains in Iceland until the 1950s and early 1960s, when a few farmers started growing barley again, particularly in the Fljótsdalur area in east Iceland, Rangárvellir in the south and east along the south coastline to Hornafjörður. In the early 1980s there was some move made to re-awaken interest in grain growing in Iceland. If it would be possible to achieve a harvest of 2 t ha^{-1} the enterprise would be profitable. As the acreage required to satisfy the need for animal concentrates could be estimated at about 35,000 ha, each Icelandic farmer would have the possibility to grow grain profitably on 10 hectares. To encourage farmers to take up grain farming it is now recommended, instead of oil-fired drying, to put poorly-mature grain as silage into fibre-glass containers, add propionic or formic acid for preservation to preserve reasonably good animal feed. If it was determined that a grain field was unlikely to attain maturity, farmers would be encouraged to cut the fields for fodder, since in such cold years there would also be reduced grass harvests and thus insufficient availability of animal fodder.“ Furthermore, he pointed out that Árni Bragason had recently carried out some cross-breeding with barley, hybridizing e.g. the early variety Mari with the old, hardy Faroe varieties Sigur and Tampar. Already some lines had been selected which were not only earlier than Mari but also hardy with higher yields. These lines were being multiplied to further test their productivity and to have the seeds grown by seed companies in one of the neighbouring countries. The RALA aim was to breed barley cultivars which could be harvested in the beginning of September with yields of 2.5 to 3.0 t ha^{-1} in favourable years. The areas to be emphasized in this re-awakening of barley growing in the 1980s, were Eyjafjöll, Fljótshlíð, Landeyjar and Rangárvellir and some areas along the coast to Hornafjördur. Fljótsdalshérað would also be a possibility and also some other parts of Iceland, depending on the success of the breeding efforts. As an associated enterprise would be growing seed of the main forage species for hay and pasture fields, primarily *Festuca rubra* and *Poa pratensis* and perhaps others which would require some 600-1000 ha to satisfy demand. In the same year, 1982, a bill was introduced in the Althing to stimulate this second re-awakening of small grain production in Iceland.

It was first around 1990 when the grain growing activities took wing again. This was a result of two positive developments: improvements in climate which warmed considerably (Global Warming?) and highly successful plant breeding led by Jónatan Hermannsson at RALA, starting around 1990. His significant breakthrough in obtaining truly high-yielding barley varieties are on par with the best yielding barleys in the other Nordic countries and often exceeding them under Icelandic conditions. From the author´s prior association with the „Green Revolution“ on the Indian sub-continent and in the Near and Far East, his view is that Jónatan´s achievements are certainly as remarkable in relative terms as the performance obtained with the use of the Japanese Norin genes in bread wheat by Norman Borlaug, and the use of the DeGeWoGin genes (Spontaneous mutants?) from Taiwan in rice at the International Rice research Institute (IRRI). It also compares with the achievements obtained by Scarascia-Mugnozza´s series of induced mutant semi-dwarfs in Durum wheat in Italy, which now are the basis for most Durum wheat production in southern Europe and the Middle East, and also to Slavco Borojevic´s superior wheats, bred in Novi Sad, then Yugoslavia, and the contribution of the

Figure 18. Comparison of Icelandic breeding lines and promising foreign cultivars of 2-row barley at Korpa 2014.

Figure 19. Comparison of Icelandic breeding lines and promising foreign cultivars of 6-row barley at Korpa 2014.

barley variety Diamand, bred by Czechoslovakian breeders to brewing barley production in Europe, all of whom I was associated with during my former U.N. activities. Similar results as those in Iceland have been achieved recently by Peruvian breeders by using induced mutations to develop barley varieties which give outstanding yields in many areas of the Andes, in some areas over 4,000 m above sea level.

According to Jónatan Hermannsson, in the three years, 2010 to 2012, the barley yields have been thus: The highest yields recorded were 8-10 t ha^{-1} in experimental plots. The average yields with the best Icelandic cultivars in field trials are 4-6 t ha^{-1}. The average yield in farmers' fields for the whole country since 2008 has been 3.2 t ha^{-1} The top two barley varieties bred by Jonatan are IsKria, a 2-row and IsSkumur, a 6-row variety. It is interesting to view the average present yields in farmers´ fields of 3.2 t ha^{-1} in comparison with the 1982 assessment by the author, related above, that if barley yields of 2 t ha^{-1} could be achieved, grain growing in Iceland would be profitable. In 1997 Jónatan stated that growing conditions in Iceland are quite different from other countries and thus it is often difficult to transfer foreign knowledge to Icelandic realities. Summers in Iceland are rather long compared to other areas at the northern limits of grain growing in our neighbouring countries, but our summers are cool and missing warm days at the time when the kernels are filling out. This is particularly true for the southern and western parts of the country Therefore, barley cultivars from our neighbouring countries, even if they are early maturing, are unable to mature sufficiently to result in fully ripe grains. Similarly, our unfavourable fall weather conditions are bad for the foreign-bred cultivars. But the Icelandic grain farmers are adapted to these conditions as evidenced by the experience on the Thorvaldseyri farm in south Iceland which has been referred to before (and gained world-fame in 2010 when the volcano Eyjafjallajökull, just north of the farm, erupted to the chagrin of thousands of air travellers in Europe and elsewhere). Barley has been grown on this farm uninterrupted since the 1950s, always giving sufficient harvest to be profitable. In addition to barley, wheat for bread-making has been grown on the farm as well as flax and oil-seed rape. The average yields from experimental fields on this farm are often higher than those obtained

from barley experiments near Trondheim, Norway, notwithstanding that summer temperatures there are 2°C higher than at Thorvaldseyri.

It was first in 1992 that Jónatan Hermannsson started cross-breeding barley under the tutelage of Thorsteinn Tómasson, a plant breeder at RALA and later it´s Director. Jónatan´s strategy was relatively simple. Early-maturing, 6-row barley cultivars which reach maturity in Icelandic summer temperatures are all too weak in structure to handle the fierce fall weather in Iceland. During dry storms the grains shatter and in orkans the spikes simply break off, or at full maturity the straw breaks in the middle. On the other hand, 2-row cultivars which can withstand these storms are all too late maturing. The simple solution was obvious: cross early maturing cultivars with strong-strawed cultivars and select the happy combinations with earliness plus straw strength. This had been tried in Iceland before but without success (also by the present author). The reason for the failure was that the gene associated with weak straw often resides on the same chromosome as the gene for early maturity. Jónatan therefore used eight different early-maturing cultivars in his crossing programme, hoping that some of the genes for earliness were located on a different chromosome. His reasoning was right and his expectation came true. He found that two of those eight cultivars contributed early maturity without weakening the straw. Both were cultivars which had never succeeded in becoming popular in Iceland, one from Trondheim and the other bred by Thorsteinn Tómasson, using the Faroe variety Tampar. The result was an early line with sufficient straw strength but low yield. Jónatan then crossed these lines with high-yielding late varieties from Sweden. Jónatan was successful indeed. There are now available several cultivars well adapted to Icelandic conditions and very high-yielding.

Figure 20. Father and son in Eyjafjörður 2004. Right: Cv. Arve, 6-row, tall and early maturing. Left: the progeny after a cross with Danish malting barley, 6-row and short with a stiff straw.

Figure 21. Barley growing by snowy mountains at Möðruvellir in autumn 2005.

One ruefully thinks back to the 1960s, wishing that these new cultivars had been available. Then again: the severe little „ice age“, which developed in that decade, probably would not have allowed any of these varieties to succeed. The present success is certainly to

the largest degree thanks to the excellent breeding work of Jónatan Hermannsson, but some can certainly be attributed to the „fearsome“ Global Warming which, whatever else can be said about this phenomenon, has in general shone rather beneficially on this North-Atlantic island. But as all farmers and all crop scientists know, even meteorologists, we do not control the climate and its whimsical nature. In Bændablaðið – The Farmers´ Weekly – from March 2013, there was an interview with a farmer, Marteinn Sigurðsson, from a north-east Iceland area called „Köldukinn“ (the cold cheek). He said: „It does not look like any seeds will be planted here this year. The fields are covered with 70 cm of snow with snow-drifts up to 5 m high. It does not look like the snow is going anywhere, anytime soon“. Marteinn had usually had 12-18 ha under barley cultivation to feed his 200 head of cattle. One could add that Marteinn´s farm is not far from Fosshóll where in 1960 the Colorado beef farmer, Bjarni Pétursson, referred to earlier, wanted to grow his own grain for his beef cattle. Although the summer of 2013 turned out to be sunny and warm in the north-east, the autumn cold and storms arrived early with bad effects on the grain fields in all parts of the country. On the whole the year 2013 turned out to be one of the bad grain years with poor results and failures in most areas. Even at Thorvaldseyri, after a reasonable summer, the fall storms played havoc with the grain still to be harvested.

In the 1960s we were optimistic and enthusiastic until our hopes froze over. That poor period ended, followed with more favourable growing seasons and the arrival of superior varieties of barley. Even if we cannot control the weather, we are lucky enough that we have some idea of how to manage the genes of our crops to adapt them to the weather conditions in Iceland in most years. No amount of breeding can prepare barley for all the vagaries of the Icelandic climate, but there is no reason to let exceptional years dampen our expectations for future grain farming in Iceland. A bad year can happen in any country in any part of the world. In a world with a population to become nine billion soon, the plant breeders will face a serious challenge in the next decades. In addition to our classical plant breeding methods, including mutation breeding, we now have all the new techniques of genetic engineering and further genetic engineering breakthroughs to be expected in the future to not only help create better grain cultivars, not only for growing grain in Iceland, but primarily to provide sufficient food for the, as it seems, uncontrollable world population growth. Perhaps there is hope that mankind can feed itself? But one cannot really blame the Icelandic farmer who sometimes smiles when he hears of the arrival of global warming!

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About the author

Björn Sigurbjörnsson was born 1931 in Reykjavik, Iceland. After graduating from the Agricultural College, Hvanneyri in 1952, he earned a B.Sc. in agriculture from the University of Manitoba in 1956 and M.Sc. in plant genetics from the same school in 1957. He studied the use of nuclear techniques in agriculture in the U.S.A., chiefly in Oak Ridge, Tennessee and earned a Ph.D. from Cornell University in plant breeding and genetics in 1960 doing his field research at the Headquarters of the Soil Conservation Service, Gunnarsholt. From 1960 to 1963 he was a research scientist at the University of Iceland´s Research Institute, Department of Agriculture where he led the research on small grains, the subject of this report. In 1963 he joined the staff of the Unit of Agriculture at the International Agency for Atomic Energy in Vienna as a plant breeding specialist and in 1964 became head of the Plant Breeding and Genetics Section of the new Joint FAO/IAEA Division of Atomic Energy in Agriculture. In 1968 he also became Deputy Director of that Division until he was appointed Director of the Icelandic Agricultural Research Institute in 1974. In 1983 he returned to Vienna as Director of the Joint FAO/IAEA Division until he returned to Iceland in 1995 to take over as Permanent Secretary of State for Agriculture in Iceland from which he retired in 2000.

Appendix I

1. FIELD EXPERIMENTS IN 1961

Korpa

Korpa, the Experimental Station of the Department of Agriculture, University of Iceland Research Institute, is not far from the former RALA Headquarters at Keldnaholt. The site was a former wetland which was drained with drainage ditches and the turf layer removed and the soil prepared for sowing. At Korpa there were a total of around 300 plots with oat and wheat trials in 1961. There were no experiments with barley at Korpa in that year.

Oats

One experiment with 53 introduced varieties was seeded on 19 and 20 May which in most years is too late for sufficient ripening. Of the 53 varieties, 26 could be harvested on 6 and 7 October. At 130 kg N and 25 kg P, the variety Orion gave the highest yield, or 1.22 t ha^{-1}, the low yield mainly due to the late seeding date. In a second experiment with 18 European varieties, with four replications and 72 plots, only 25 plots were ripe enough to be harvested. The highest yielding varieties were Blixt from Sweden and Kytö from Finland. There was also a trial with four oat varieties, tested with six different rates of fertilizers, sown on 19 May. Yield of the best three varieties varied from 0.8 to 1.2 t ha^{-1}. The increase in yield when P fertilizer was raised from 18 to 25 kg ha^{-1} was 150 kg ha^{-1}. Another experiment was laid out for measuring various parameters: earliness, height, shattering and lodging. There were significant differences between the varieties with respect to the different parameters measured. Graphs with the results were presented in meetings with farmers and agricultural advisers. Another experiment tested varieties × fertilizer rates (NPK) with 24 variables, four replications in 96 plots, using the quadruple- partially balanced lattice square design. These were all statistically analysed and the results used in recommendations and presentations but never published.

Wheat

The breeding effort at Korpa included 40 plots with segregating F_3 lines provided by Drs. Thorvaldur Johnson and Bjorn Petursson of the Rust Research Laboratory, Manitoba, Canada. There were trials with 45 varieties which came from Weibull Seed Co. Sweden and from breeding stations in Norway and Finland. The highest yields were from the Canadian variety Selkirk, or 1.54 t ha^{-1}, a Weibull line from Sweden, 1.3 t ha^{-1}, Apu, Finland, 2.0 t ha^{-1} and Vakka, Finland 1.86 t ha^{-1}. The experiments were seeded on 7 May and harvested 4-5 October. The fertilizer rates were 60 N, 100 P and no K. The Manitobans also provided 26 F_3 lines from Dr. Kaufmann, Lacombe Alberta, Canada. No results for these lines are available.

Gunnarsholt

The area is located just south of the volcano Hekla. The bulk of the cereal trials in1961 were carried out at Gunnarsholt, the Headquarters of the State Soil Conservation Service, with emphasis on barley. There were also trials with oats and wheat. The experiments on barley were duplicated with one set on cultivated hayfields and the other on the eroded sands surrounding Gunnarsholt. These eroded lands were common throughout the area south of the volcano Hekla, until the Soil Conservation Service succeeded in bringing most of the area under vegetative cover.

Cultivated hay lands – The highest yields in barley were found for the varieties Jøtun, 2.59 t ha^{-1}, Fløya 2.22 t ha^{-1} and Edda 2.0 t ha^{-1}, all 6-row varieties from Norway.

Sandy soil – The highest yielding varieties were Herta, a 2-row variety with 2.75 t ha^{-1}, Edda, a 6-row variety with 2.0 t ha^{-1}, both from Sweden and Jøtun with 1.99 t ha^{-1}, a 6-row variety from Norway, all at the highest N fertilizer application, 130 kg ha^{-1}. There was a linear increase in yields as rates of N fertilizer increased.

The following are examples of results from barley experiments on loam and sandy soils at Gunnarsholt in 1961:

Lodging: The effect of increased N on the cultivar Edda: With 50 to 90 kg N ha^{-1} the score given went from 100 (no lodging) to 80, but increasing N from 90 to 130 kg ha^{-1} did not result in more lodging. Lodging decreased with increasing levels of P

Shattering: There was a linear increase in shattering with an increase from 50 to 130 kg N ha^{-1}. Another experiment with 6 varieties showed that shattering increased with higher levels of both N and P. The rate of shattering was higher in 6-row than 2-row varieties.

Ripening: There was a linear delay in ripening with an increase in N from 50 to 90 kg ha^{-1} but no further delay in ripening when the rate was increased to 130 kg ha^{-1}. The speed of ripening differed much between the loam and sandy soils. The scores given for ripening were six times higher on the eroded sand compared to the old hayfields, regardless of levels of N fertilizer.

Spacing: A study on the effect of spacing using the 2-row variety Herta showed a yield of 1.9 t ha^{-1} at 15 cm and 0.9 t ha^{-1} at 45 cm.

Yield: Sandy soil: On eroded sands there was a linear increase in yield from 1.1 to 1.4 t ha^{-1} with increasing rates of N fertilizer applications from 50 to 130 kg ha^{-1} and P to 25 kg ha^{-1}. At 18 kg ha^{-1} P the yield of the variety Edda increased linearly from 0.65 to 1.3 t ha^{-1} with rates of N at 50, 90 and 130 kg ha^{-1}. The 2-row variety Herta showed an increase in yield from 0.75 to 1.35 t ha^{-1} as N rate increased from 50 to 90 kg ha^{-1}, but its yields decreased at higher levels of N fertilizer. Another experiment on the sandy soil with four replications was sown on 18 May. Applications of 25 kg ha^{-1} of P with N levels rising from 90 to 130 kg ha^{-1} gave an increase in yield in the highest 2-row varieties from 1.2 to 1.9 t ha^{-1}. An increase in N from 50 to 90 had no effect. Two 6-row varieties increased from 1.0 to 1.4 t ha^{-1} when N increased from 50 to 130 kg ha^{-1}. Another experiment with barley on the sand with 6 varieties and four replications and variable levels of both N and P showed an increase in yield from 0.75 to 1.1 t ha^{-1} at 90 kg P and 0.94 to 1.35 t ha^{-1} at 130 kg P ha^{-1} when N was increased from 50-130 kg ha^{-1}.

Loam soil: In a barley experiment, seeded 30 May, an increase in P from 18 to 25 kg ha^{-1} raised yield from 0.65 to 0.8 t ha^{-1} while increasing N had no effect. These low yields primarily reflect the late sowing date, with the plants not reaching full maturity. With sowing dates in early May at 25 kg P and 50, 90, and 130 kg N ha^{-1} the 6-row varieties Fløya yielded 1.4 to 2.6 t ha^{-1}, Edda 0.75 to 1.95 t ha^{-1} and Jøtun 1.7 to 1.9 t ha^{-1}, whereas the 2-row Herta variety decreased in yield from 1.75 to 1.15 t ha^{-1} mostly due to its late ripening.

Table A1. Overall summary of highest barley yields at Gunnarsholt in t ha^{-1} in 1961.

Variety	Sandy soil	Loam soil	Former Hayfields
Herta 2-row	1.91	0.63	0.63
Jøtun 6-row	1.38	1.28	1.92
Edda 6-row	1.41	1.00	1.97
Fløya 6-row	1.08	1.28	2.07

Yield trials with 36 oat varieties were conducted on eroded, sandy soil. The variety Orion III gave the highest yield or 4.25 t ha^{-1}. The three next highest gave 3.6, 3.5 and 3.1 t ha^{-1}. On 14 May, 45 varieties of wheat were seeded on eroded sandy soil and were harvested 4-5 October. There is no information on performance available. In retrospect, looking at these results, one wonders why farmers did not pay more attention to growing oats.

2. FIELD EXPERIMENTS IN 1962

Breeding of barley, oats and wheat with selection of lines from both hybridization and progeny from radiation treatments

Some hybridization was attempted at the Korpa Experimental Station in Reykjavik, but without greenhouse facilities this was difficult to do. Like in 1961 most of the breeding material was provided by colleagues abroad. Prof. Sigurdur Helgason at the University of Manitoba did hybridizations on material we sent to him. The F_1 material was grown at Gunnarsholt. A classmate of the author, Prof. Peter Dyck of the University of Manitoba, then director of an experimental station in Ottawa, hybridized some selected oat varieties, the F_2 of which were grown and selected from at Gunnarsholt. Drs. Thorvaldur Johnson and Bjorn Petursson of the Rust Research Laboratory in Manitoba again provided both hybridized and irradiated wheat material. The Manitoba scientists, with the exception of Peter Dyck, being of Icelandic lineage were especially interested in helping with the breeding work. Prof. Arne Hagberg, Svalöf, Sweden sent us segregating material and mutants of barley. Further selections were made in the composite cross population of barley obtained from the USDA in California and the selected spike progenies planted in the spring of 1963 and again in 1964. After that the unfavourable weather conditions resulted in steadily reduced number of the plants reaching sufficient maturity to produce fertile seeds. There were 10 trials devoted to selection in segregating lines provided by our overseas colleagues, all located at Gunnarsholt. Breeding test no. 116-62 compared the progeny of three Swedish barley crosses with the 2-row variety Herta. Trial no. 117-62 had 20 selected M_3 lines of irradiated wheat from Manitoba with the Finnish variety Apu as control in every 5^{th} row. The M_2 generation had been grown at Korpa the year before. No. 118-62 compared six breeding lines of wheat with introduced varieties, all from Sweden and Finland. Trial no. 119-62 tested M_2 Pembina wheat lines from Canada which had been treated with gamma rays. No. 120-62 had four segregating wheat lines together with four wheat cultivars. Trial no. 121-62 had 39 M_3 lines of irradiated wheat, the seed taken from the same plants at Korpa from which selection lines were sown in trial 117-62. In trial no. 123-62, 1700 g of the California composite barley cross seeds were planted in 30 m rows. In trial no. 124-62 there were selections from Sweden of eight crosses with the 6-row barley variety Edda. Each selection was planted in three 3-m rows. Trial no. 125-62 had 13 selections in 6 m^2 plots from barley crosses obtained from Finland and Sweden. No. 126-62 had 42 advanced lines of oats from Finland for selection. In trial no. 127-62 there were 19 F_1 lines from hybridization between two oat varieties. Another trial no. 128-62 compared 6 selections of hybridized oats. The last of these series, trial no. 129-62, compared 12 oat selections from Finland.

Comparison of cultivars and lines

Four experiments were made with about 100 varieties of barley, oats and wheat in randomized blocks with 4 replicates and 6 m^2 plot sizes. There were also a number of observational trials with additional varieties and lines. As all the varieties in these trials are now obsolete, there is no point in presenting analysis of their performance now, 50 years later. It is interesting to note that in most of the comparative trials with wheat, the two Manitoba varieties Selkirk and Pembina yielded higher than varieties from Norway, Sweden and Finland.

Fertilizer trials

Studies were made on the effect of different rates of NPK fertilizers on development, yield and various other parameters using some of the main barley cultivars then used in farmers´ fields. The results were used in recommendations to farmers and agricultural advisers.

Country-wide trials

The main location besides Korpa and Gunnarsholt was Skógasandur, east of Gunnarsholt where three experiments were carried out, comparing cultivars and different levels of fertilizers. A total of 15 smaller-scale trials were carried out at 11 locations throughout Iceland with the assistance of agricultural advisers, both at the State Experimental Stations and on farmers' fields.

3. FIELD EXPERIMENTS IN 1963

Korpa

No. 002-63. A comparison trial with 24 barley varieties in a randomized- block design with four replications, 96 plots, 6m^2. The highest yield was Sigur, 1.45 t ha^{-1}. Most varieties ranged from 0.5 to 0.9 t ha^{-1}.

013-63. In a trial comparing 12 oat varieties, the highest yield was 0.76 t ha^{-1}.

123-63. Comparative trials with 18 barley varieties, 12 lines from the USSR and 6 other lines. A similar trial was made with 25 oat varieties.

A breeding project with hybridizations done 19-25 July using the barley varieties Asa, Edda II, Olli × Fløya, Sigur, Gateway, Union, Herta and Mari. The F_1 seeds were planted in 1964 at Korpa.

Gunnarsholt

Sandy soils. No. 001-63. Comparative trial with 18 varieties of barley. The highest yields were in Goliat and Union, both 2.0 t ha^{-1} and Mari 1.64 t ha^{-1}.

No. 009-63. Comparative trial with 40 varieties of barley and one wheat variety. The trial was completely destroyed by drought and sand storms.

No. 017-63. Comparative trial with 10 oat and one wheat variety. The highest oat yield was Pendek 0.45 t ha^{-1}. No information is available on the Selkirk wheat. There were three experiments with different fertilizer rates of N, P and K for barley with 24 plots. The mean yield in one experiment was around 0.5 t ha^{-1}. Another experiment tested very high fertilizer rates, up to 700 kg N, 120 kg P and

200 kg K ha^{-1} on 2-row barley on eroded sand soil. There is no information on yield but ripening was drastically slowed down by the highest rates.

Skógasandur

The fate of the experiment testing different sowing times, 018-63, has been related above. Other experiments were the following:

003-63. Comparison of 6 barley and 4 oat varieties with 40 plots, 20 m^2 each. The highest barley yield was Proctor from the UK, 0.8 t ha^{-1} and the oat variety Blixt from Sweden, 1.25 t ha^{-1}.

008-63. Comparative trial with 18 wheat varieties and one 2-row barley and one rye variety, 36 plots, 6 m^2 each. The highest yielding wheat was line M.G.H. with 0.3 t ha^{-1}. The barley variety Herta had 0.52 t ha^{-1}. The rye did not survive.

014-63. Study on different fertilizer rates using Herta barley with four replications and 32 plots, 10 m^2 each. The rates were 100 and 200 kg N; 20, 40 and 60 kg P, and 10 and 50 kg K ha^{-1}. The highest fertilizer rate gave the highest yield, 1.0 t ha^{-1}, the lowest score for ripening, the highest 1000 kernel weight and the strongest straw. The lowest rate gave the lowest figures in all properties except ripening where it was the highest. The agricultural adviser for the area, Einar Thorsteinsson, reported on the cereal fields grown by farmers on Skógasandur in 1963: Herta barley on 28 ha with 0.3 t ha^{-1}; Same oats on 2 ha with 0.4 t ha^{-1}; Norrøna wheat on 3 ha with 0.5 t ha^{-1}. On the nearby farm Thorvaldseyri, barley on 2.5 ha on better soils gave a yield of 1.5 t ha^{-1}.

Country-wide trials on experimental farms and in farmers' fields

Like in 1962, cereal trials were carried out by agricultural advisers, heads of Experiment Stations and farmers at different places in Iceland in collaboration with the University of Iceland Research Institute. These trials were located in the following sites:

South- Iceland:

- Thórustaðir near Selfoss. Trial with five barley varieties, six plots, 10 m^2 each. No results are available.
- Mýrdalssandur, near Hafursey (the large black desert sand created by the Katla eruption in 1918). Three barley varieties and one each of oats and wheat, 10 plots, 6 m^2. The supervisor, agricultural adviser Einar Thorsteinsson, reported that „this trial came out negatively for Mýrdalssandur".
- Öræfi (Kvísker and Fagurhólsmýri). Trial with two varieties each of oats, barley and wheat, 12 plots, 6 m^2, 2 reps. at each location. Wheat (Apu) was also sown at Svínafell. The supervisor Halldór Björnsson, the farmer at Kvísker reported: „Harvested on 16 September. The yield was very low. Highest number of spikes in a plot was 10, most on wheat and least on oats. Too few grains to bother weighing. Other remarks: Bonus (Swedish barley): Very little vegetative volume. Clear signs of nutritive deficiencies. The kernels were few but fully formed. Eko oats: Reasonable growth, some of the kernels fully ripe, others green. Apu wheat: Small growth, small shrunken kernels. The yield of the barley was 0.4 t ha^{-1}".

East- Iceland:

- Egilsstaðir. Trial with 30 barley varieties. 30 plots with 2 rows each. Supervisor: Páll Sigbjörnsson, the agricultural adviser for the area. He reported that he had harvested the plots with sheep shearing scissors. The highest yield was 0.64 t ha^{-1} in the variety Union.

- Fljótsdalshérað (Breiðavað). Trial with nine barley, two oat and one wheat varieties, 48 plots, 6 m^2, four replications. Supervisor same as above. Highest yield by Edda, 1.1 and Fløya 1.0 t ha^{-1}. Another trial with different fertilizer rates on a drained bog in Eiðathing. The fertilizer rates tested were 30 and 60 kg N ha^{-1}, 8, 24 and 40 kg P ha^{-1} and 25 kg K ha^{-1}, two barley varieties in two replicates with 36 plots, 6 m^2 each, also carried out by Pall who reported that the trial was quite successful except that germination was rather poor due to insufficient cultivation of the soil. At the end of September the 2-row varieties were poorly mature but the 6-row varieties more advanced. Pall also reported that before harvesting could be attempted the geese had already been there ruining the trials by stocking up on energy before the transatlantic flight to Britain.
- Skriðuklaustur, a State Experimental Farm, south of Egilsstaðir. A trial with six barley varieties and two rates of N and P fertilizers. Supervisor Matthías Eggertsson. No results were reported.

North-east Iceland:

- North -Thingeyjarsýsla, Sandfellshagi and Ærlækjarsel farms. A trial with five barley and two oat varieties on both loam soil and on eroded sand carried out by the agricultural adviser, Grímur Jónsson. He reported that the trial had been damaged by sheep. On 29 August the spikes had just emerged.
- South- Thingeyjarsýsla. Öxará farm. A trial with eight barley and two oat varieties in 40 plots, 6m^2 each, carried out by Skafti Benediktsson, agricultural adviser for the district and the beef cattle farmer at Fosshóll, Bjarni Pétursson. Probably failed as there are no results reported.

North- Iceland:

- Akureyri. On the State Experiment Station, two trials, supervised by the station Head, Árni Jónsson, were carried out on barley and another one on oats and wheat. Probably failed as there is no information on results.
- Skagafjörður, Messuholt farm. A fertilizer trial with four barley and one oat variety carried out by the agricultural adviser, Sigurthór Hjörleifsson. There were three different soil types: drained bog, loam and gravelly sand. Sigurthór reported that on 28 August the spikes had not emerged and that the stands were very thin. „hopeless to expect ripening“. (note: in 2012 this location was one of the most successful grain growing areas in Iceland).

North-west Iceland:

- Húnavatnssýslur, Barkarstaðir farm. A fertilizer trial with six barley and one each of oats, wheat and rye varieties. A total of 71 plots, 6.6 m^2 each, carried out by Ragnar Benediktsson. Sown on 23 April. No results reported.
- Akur, Haukagil and Hvammur farms. Trials with four barley and one oat variety carried out at the three locations, two on loam soil, one on gravelly sand carried out by the agricultural adviser, Sigfús Thorsteinsson. On 28 August he reported that sheep had damaged the plots, the vegetative growth was vigorous but no hopes that the grain will ripen.
- Teigingalækur and Prestbakki farms. There were trials with four barley varieties on both farms where the highest yield was in the X-ray mutant variety Mari with 1.9 t ha^{-1} on the former and 2.32 t ha^{-1} on the latter farm.
- Strandasýsla on the farms Fjarðarhorn, Fell and Staður. Trials with four barley and one oat variety at the three locations were carried out by Brynjólfur Sæmundsson, the agricultural adviser. There were 30 plots, 6 m^2 at each location. Brynjólfur reported that on 26 October it was confirmed that none of the trials had resulted in mature grains.

South-west Iceland:

- Bæjarsveit, carried out by Magnús Óskarsson, teacher at the Farmers School, Hvanneyri. There was a trial with three barley varieties and eight combinations of fertilizer rates. The highest yield was 0.61 t ha^{-1} for the 6-row Edda variety.
- Kiðafell farm, 30 km north of Korpa Experimental Station. A trial with four barley and one oat variety, 10 plots, 6 m^2 on a dry river bank carried out by the farmer, Hjalti Sigurbjörnsson. Sowing time was 17 May on a cold day. Hjalti reported that on 21 October he went to harvest the plots and discovered that geese had completely eaten all the plants and then headed for more favourable weather conditions.
- Akranes, a town across the Faxaflói bay from Reykjavik. A trial with two varieties each of barley and oats, eight plots, 6 m^2, carried out by Halldór Stefánsson. No results are available.

It would seem that the bad weather and the migrant geese had teamed up to ruin much of the experimental plots around Iceland in 1963.