

Genetic variation in Danish and Norwegian germplasm collections of hops



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ABSTRACT

The germplasm collections of hops (*Humulus lupulus* L.) in Denmark and Norway are maintained in clonal archives funded by the national authorities. The plants have been collected over the last decades as part of a strategy to conserve plant genetic resources for future generations. The major part of the various collections consist of plants collected in villages and gardens. About 20% are plants used for breeding, mainly kept in a collection at Carlsberg, Denmark. In order to identify any duplicates and with a view to learning more about the various collections, a DNA fingerprinting study was initiated, analysing 62 Danish and 34 Norwegian clones with a set of five amplified fragment length polymorphism (AFLP) markers. The AFLP analyses resulted in 41 polymorphic bands and were able to separate the majority of the Danish and the Norwegian accessions. UPGMA dendrograms showed 21 accession groups, and potential duplicates were found within 13 of these groups. Principal coordinates analysis revealed that plants were differentiated according to country of origin. In addition, regional separation of the plants within each country was also detected, and similar levels of diversity were found in the Danish and the Norwegian collections. Compared to the rest of the plants, there was less diversity within the Carlsberg material. For the Norwegian as well as a part of the Danish collection, morphological characterisation and chemical analysis was carried out, allowing a comparison of these to the AFLP data. A correlation with AFLP bands and both morphological and chemical characteristics was detected. The most promising results for further breeding was an association of AFLP bands with the content of colupulon in the cones, measured by relative values compared to the total alpha acid content. Further studies are needed to verify such an association with the potential to develop a PCR-based marker for hop breeding carried out in the clones now analysed with AFLP markers, making it possible to search for any association between AFLP data and phenotypic data.

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1. Introduction

Hops (*Humulus lupulus* L.) originate in China (Neve, 1991; Murakami et al., 2006), but have been cultivated in the Nordic region since mediaeval times (Zachrisson 2000). Under the Nidaros archbishopric, farmers in the fifteenth century were obliged

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to clear land for ten new hop plants every year (Borgen, 1999). This requirement was later reduced to six plants, but the legalisation remained under the Danish and Norwegian Union until the mid-eighteenth century. The climate permitted hop cultivation all the way to the Lofoten islands (68°N, 14°E), Northern Norway. Danish and Norwegian hop production declined markedly in the nineteenth century as a consequence of the centralisation of breweries and the importation of cheaper hops from Germany. This can be illustrated by figures from Denmark. Hop production fell from 1103 ha in 1881 to 200 ha only 20 years later, before almost disappearing in the twentieth century (ibid). Hop production in Scandinavia is now very much related to historical practices, but new trends may lead to changes in this regards. Culinary concepts such as *New Nordic Food* and *Local food* have focused on unique and local ingredients, with beer being one of the products that form part of this trend.

In beer production only the female hop plants are used; the inflorescences (cones) are used as flavour and as a preservative. The actual compounds belong to the alpha-acids (humulone, adhumulone, colupulon and cohumulone) and the essential oils (humulene, myrcene, caryophyllene and farnesene). Among the alpha acids, cohumulone has been regarded as unpleasant bitterness, while the other alpha acids are regarded as more favourable. Furthermore, on the basis of the content of alpha acid, cultivars are divided into two groups; aroma hops and high alpha acid hops. The content in what is called aroma hops is assumed to be similar to the wild hop, while the latter group has been developed to meet specific needs for the brewing industry.

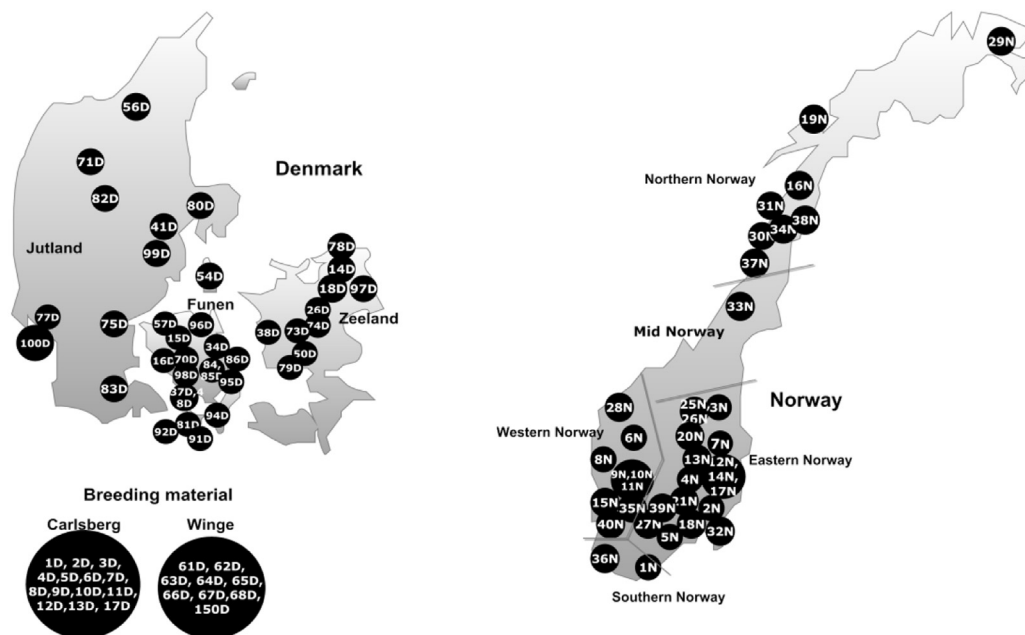
Hop plants can be found throughout both Denmark and Norway, often as relics from earlier cultivations, and resembling the finds of hops in Sweden described by Karlsson Strese et al. (2012). The plants may be old cultivars (whose identity is lost) or local, naturalised clones, or even populations. Since the identity and properties of the plants are mostly unknown, plants have been collected and maintained in clonal archives for further characterisation and evaluation. Our study is part of this work.

The objectives were to assess any potential duplicates in these collections, but also to find out more about the genetic variation within and among the collections. We also wanted to search for any correlation between genetic characteristics and geographical, morphological or chemical data. Genetic studies of germplasm hop collections have been carried out before (see for example Jakse et al., 2001; Patzak et al., 2010; Karlsson Strese et al., 2012), but our study is the first on the Danish and Norwegian collections conserved under the national programmes for conservation and use of plant genetic resources.

2. Material and methods

2.1. Plant material

A total of 100 single plant samples (clones) were included in the study, 62 from Denmark (D), 34 from Norway (N) (Fig. 1), and 1 from Sweden (S), Finland (F), Germany (G) and England (E) each.



Local plants from Denmark (number and D) and Norway (number and N) and the breeding material from Carlsberg and Winge in Denmark (number and D). In addition there was one sample from Sweden (8S), one from Finland (41F), one from Germany (58G) and one from England (59E).

Fig. 1. Geographical origin of the plants Local plants from Denmark (number and D) and Norway (number and N) and the breeding material from Carlsberg and Winge in Denmark (number and D). In addition there was one sample from Sweden (8S), one from Finland (41F), one from Germany (58G) and one from England (59E).

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