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Evaluation of yield and alpha acid content in selected hop varieties

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Abstract

The stability of the agricultural and technological properties of hop varieties over the course of time and under changing climate is essential for both growers and brewers. This study is a typical case of monitoring 12 hop varieties selected from a collection of hop genetic resources, that were evaluated in the years 2009 to 2021. The assessed parameters were the hop yield and content of alpha acids with a focus on the variability/stability of this characteristics. Only the Pilgrim and Target hop varieties from England showed exceptional hop yield above 3 kg/plant. On the other hand, the lowest hop yield was obtained from the Saaz and Bramling Cross hop varieties, i.e. below 1.5 kg/plant. The lowest variability of hop yield – below 30% – was found in the Savinjski Golding, Bramling Cross and Saaz hop varieties. In contrast, the Bobek, Aurora, Pioneer and Phoenix hop varieties demonstrated the highest variability of hop yield, i.e. above 50%. Further, also Target and Phoenix have the highest content of alpha acids, namely 9.68% w/w and 9.56% w/w, respectively. The lowest content of alpha acids was determined in Saaz, which was the only hop variety with an alpha acid content below 3.0% w/w. The Premiant, Target and Aurora hop varieties exhibited a variability of alpha acid content below 20%. On the contrary, the Bobek and Pilgrim hop varieties had the highest variability of alpha acid content, namely above 30%.

Keywords: hop, *Humulus lupulus* L., hop yield, alpha acids, variability

1 Introduction

The Hop Research Institute in Žatec has a broad selection of genetic resources of hops, divided into two collections. The first collection includes the world´s hop varieties and is administered within the National Program of Conservation and Utilization of Genetic Resources in Plants and Biodiversity, which is supported by the Czech Ministry of Agriculture. A field compilation consists of semi-finished breeding materials, registered hop varieties and wild hops (Charvátová et al., 2017). The collection currently contains 380 items. The second collection is comprised of wild hops, which have been collected on a regular basis by the Hop Research Institute in Žatec during expeditions since 1997 (Nesvadba et al., 2022a). This collection currently contains 295 wild hops: 128 from Europe, 73 from North America, 76 from the Caucasus and 18 from several parts of Russia (e.g. Altai, Kyrgyzstan or Kamchatka).

The evaluation is performed every year with the use of a classifier (Rígr and Faberová, 2000). Many significant characteristics are evaluated in hop varieties, including hop yield, content and composition of hop resins and essential oils, hop aroma and mechanic analyses of dry hop cones. These characteristics are the indicators that de-

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termine differences between hop varieties. The resulting data are transferred to the genetic resources information system, GRIN Global, which was provided free of charge to the Gene Bank of the Research Institute of Crop Production (VÚRV, v.v.i.) by USDA/Agricultural Research Service (National Germplasm Resources Laboratory – NGRL, Database Management Unit – DBMU, Beltsville), an entity operating the system. GRIN Global was developed from the original GRIN documentation system in cooperation between USDA Agricultural Research Service, Biodiversity International and Global Crop Diversity Trust (Nesvadba and Charvátová, 2019).

Genetic resources of hops constitute the basis for hop breeding. They are very important for the breeding of aroma hops, bitter hops and flavour hops. Recently, hop breeding has focused on drought resistance (Nesvadba et al., 2022b).

A broad variability of genetic resources of hops is indispensable so that set breeding objectives could be achieved. Hop varieties are characterized by their yield, resistance to diseases and pests, and sensitivity to agrotechnical interventions. Other significant features are the content and composition of hop resins and essential oils (Nesvadba et al., 2020). These characteristics guarantee the performance of the hop variety. However, the stability of quantitative and qualitative parameters is an important characteristic of hop varieties as well. Due to weather conditions, there has been a lack of precipitation in recent years, that has had a negative impact on quantitative and qualitative parameters of hop varieties (Krofta et al., 2019; Krofta et al., 2020). Therefore, the research project QK21010136 entitled "Application of new hop varieties and genotypes resistant to drought in hop growing and beer brewing" is currently underway, being carried out from 2021 to 2025 (Nesvadba et al., 2022). However, it is important to note, that the lack of precipitation is only one of several parameters that have an impact on the stability of the above mentioned characteristics.

The aim of this study is to evaluate the stability of the typical variety properties during the growing period 2011–2021. It is a practical assessment of the performance (un)stability of selected varieties, which is fundamental for beer brewing.

2 Materials and methods

The evaluation was performed in the years 2011 to 2021 within the collection of genetic resources of hops. The collection is located in Stekník, near Žatec. The applied agrotechnology, hop nutrition and protection were in line with the relevant hop growing methodology. The evaluated genotypes were grown under the following conditions:

The hop field: this was located at an altitude of 215 meters in the Žatec hop growing region and the Ohře River Basin hop growing location. The region is warm and dry. The sum of temperatures above 10 °C amounts to 2600–2800 °C per year.

Soil characteristics: from a pedological perspective, there are light alluvial soils with colluvial and alluvial sediments, which can get dry.

Soil angle: a complete plain with no signs of sheet water erosion, the land is exposed on all sides. The soil is skeletonless no more than 60 cm deep.

Aroma hop varieties were selected and divided by their country of origin:

- Czech Republic: Saaz, Sládek and Premiant,
- England: Bramling Cross, First Gold, Target, Pioneer, Pilgrim, Phoenix
- Slovenia: Savinjski Golding, Aurora, Bobek

As for all the hop varieties, a non-revived planting stock was planted.

The evaluation of genotypes was performed on the basis of monitored breeding. The hops were harvested at the time of their maturity using the experimental Wolf hop-picking machine. The harvest time depended on the climatic conditions of the particular year. The yield was specified in kg of fresh hops/plant. The content of alpha bitter acids was determined from dry hop cones using liquid chromatography method (EBC 7.7) (Krofta K., 2008).

The average (x) and standard deviation (s) of obtained values were calculated. Relative amount of variability was used to compare a set with different levels. Resulting variability amounts were dimensionless numbers expressed in %. This made it possible to compare the variability of statistical characteristics differing in measure units. Coefficient of variation (CV), showing the extent of variability in %, was used for data processing. The t-test was applied to determine the difference between hop varieties. The difference of sets was determined on the basis of significance level (α), which shows the probability of difference of the tested sets (Meloun and Militký, 1994). For example, an established level of significance where α = 0.01 suggests that the evaluated sets were different with a probability of 99%.

3 Results and discussion

One of the basic characteristics of all cultivated plants is their yield, which indicates the productivity as well as profitability of the particular variety. Figure 1 shows the average yield of the tested hop varieties in the period between 2009 and 2021, expressed in kg fresh hop cones per

plant. Based on their yield, the varieties were divided into groups. Only the Pilgrim and Target hop varieties from England reached the hop yield above 3kg/plant as demonstrated in Figure 1. However, both hop varieties had a significantly higher yield at the 99% probability level only when compared to hop varieties yielding below 2.0 kg/plant. The second group comprised hop varieties which showed values above 2.0 kg/plant, i.e. Pioneer, Bobek, Sládek, Premiant and Phoenix. With a probability of 99%, these hop varieties showed a significantly higher yield than Saaz and Bramling Cross, which demonstrated yields below 1.5 kg/plant. The third group consists of hop varieties with a balanced average yield ranging from 1.93 kg/plant (Savinjski Golding) to 1.88 kg/plant (First Gold). This group demonstrated a significantly higher hop yield than Saaz and Bramling Cross with a 99% probability. The results revealed that the oldest hop varieties – Saaz and Bramling Cross – had the lowest hop yield. It is interesting to note that the Pilgrim and Target hop varieties from England show the highest hop yield even under the usual conditions in the Czech Republic.

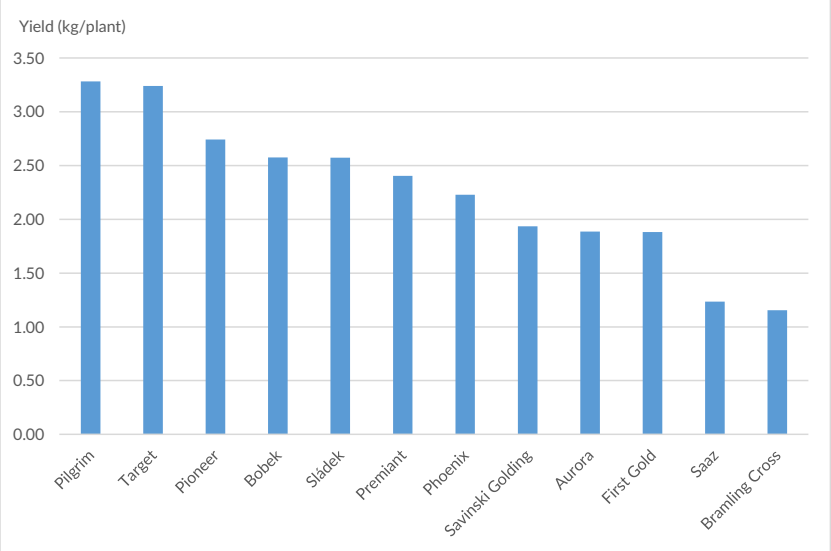

Figure 1 *Average yield of the monitored hop varieties in the years 2009 to 2021*

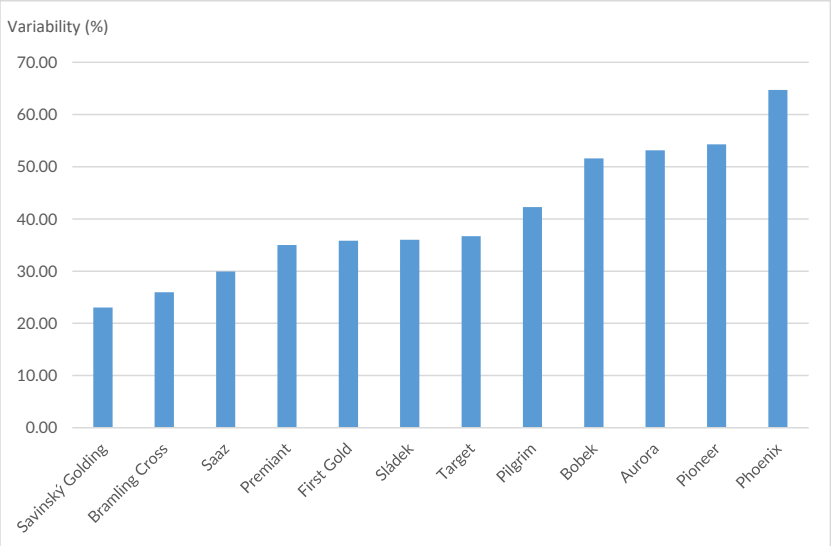

Figure 2 *Average variability of hop yield in the years 2009 to 2021*

Figure 2 represents the variability in yields of the tested varieties and period. Savinjski Golding, Bramling Cross and Saaz showed the lowest variability below 30%. In contrast, the highest variety of hop yield above 50% was found in Bobek, Aurora, Pioneer and Phoenix. Such variability is very high for hop growing and does not guarantee the needed yield stability. The Phoenix from England reached a yield variability 64.71%, which is absolutely unsuitable for hop growing. For the Czech hop varieties, the current results correlate with variability established in the years 2014 and 2019 (Nesvadba et al., 2021). The variability of hop yield in the Czech hop varieties ranged between 21.88% (Saaz) and 28.49% (Premiant).

The content of alpha acids in tested hop varieties is summarized in Figure 3. The highest level of alpha acids was found in Target (9.68% w/w) and Phoenix (9.56% w/w). With a 99% probability, these hop varieties had a significantly higher content of alpha acids than the remaining hop varieties. The second group based on alpha acids consisted of Pilgrim, Pioneer, Aurora, First Gold and Premiant, which demonstrated a higher amount of alpha acids than the third group including hop varieties with an alpha acid content below 6% w/w. Saaz showed the definitely lowest content of alpha acids, being the only hop variety with an alpha acid content below 3.0% w/w. Saaz is the only hop variety that was obtained from a selection of the original population of Žatec (Saaz) hops. The other

hop varieties were bred from a selection of the best genotypes following intentional hybridization. The results achieved in Czech hop varieties correlated with results from the years 2010 to 2019, with Saaz having an alpha acid content of 2.87% w/w, Sládek 5.94% w/w and Premiant 7.54% w/w (Nesvadba et al. 2020).

It is also necessary to deal with a variability of the alpha acid content, which informs about the stability of this varietal characteristic. It is evident from the Figure 4 that the lowest variability of alpha acid content was found in Premiant (13.19%). Further, Target and Aurora demonstrated variability of alpha acid content below 20% as well. On the contrary, the highest variability was determined in Bobek and Pilgrim, i.e. above 30%. The other hop varieties showed this parameter between 20% and 30%. The results achieved in Czech hop varieties fully correlate with the results of variability evaluations performed in the years 2010 to 2019 (Nesvadba et al. 2020), with Premiant having a variability of 14.14% and Sládek and Saaz between 20% and 30%. None of the Czech hop varieties displayed variability exceeding 30% like the Target and Aurora hop varieties, which are characterized with parameters unsuitable for hop growing under the conditions which are usual in the Czech Republic.

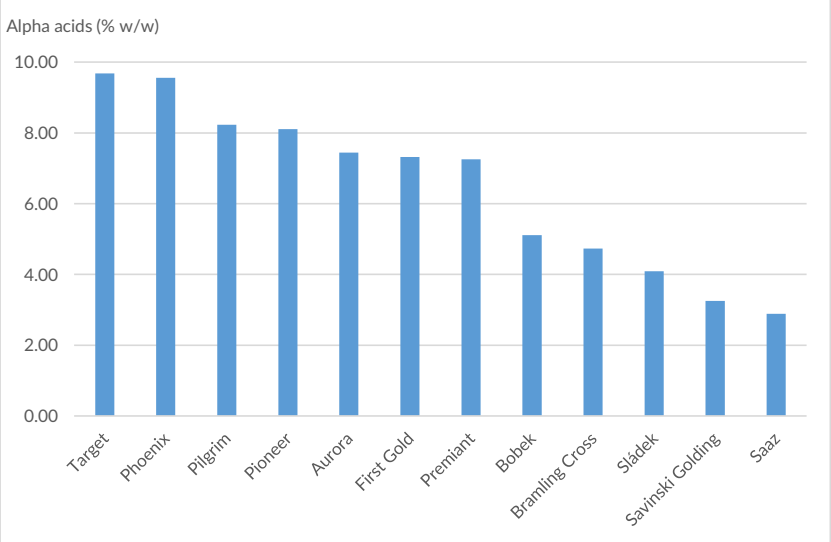

Figure 3 *Average alpha acid content of the monitored hop varieties in the years 2009 to 2021*

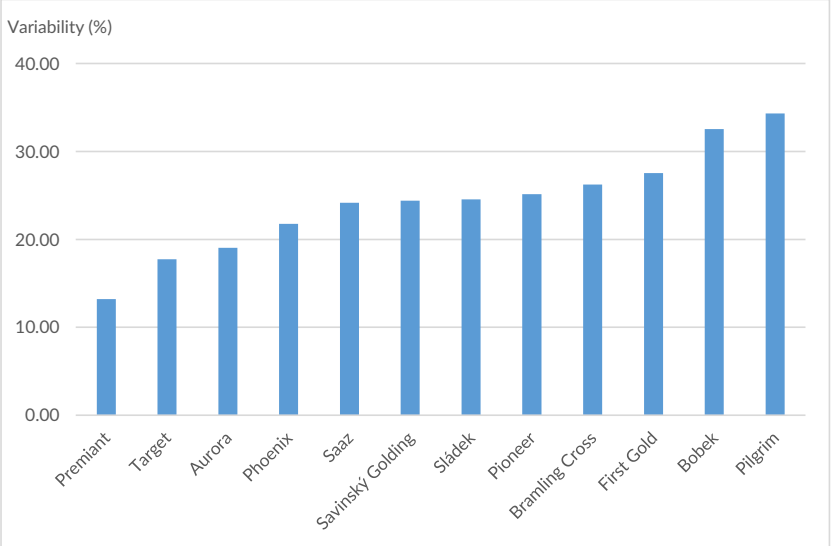

Figure 4 *Average variability of alpha acid content in the years 2009 to 2021*

4 Conclusion

The results achieved are of great importance for hop breeding aimed at drought resistance. The varieties Target, Premiant and Sládek were suitable in terms of hop yield. These varieties provide a higher hop yield than hop varieties with lower yield variability, i.e. Savinjski Golding, Bramling Cross and Saaz. The variability of the first-mentioned varieties is at a good level. Regarding alpha acid content, it is most important to monitor and evaluate their variability, because the content of alpha acids is a one of the key characteristics of a particular hop variety, especially for brewers. Bitter hop varieties such as Target demonstrated an alpha acid content above 10% w/w. In contrast, fine aroma hops such as Saaz showed only 3% w/w of this content. The obtained results suggested that all hop varieties except Bobek and Pilgrim reached the average variability of alpha acid content below 30%. The results did not show only which hop varieties would be suitable for growing in the Czech Republic but also indicated which ones could be used as parent components for hybridization. These parents would provide descendants with low variability

in yield and alpha acid content. It can be concluded that Premiant, Target and Sládek are the best varieties for hybridization.

5 Acknowledgement

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