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Patterns for improved storability of sugar beet – importance of marc content and damage susceptibility of varieties in different environments

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ABSTRACT

Differences in the storability of sugar beet genotypes have been reported to be related to the marc content of beets. Hence, this study aimed at identifying 1) general patterns to characterize varieties and growing sites for low storage losses, 2) the causal relationship between marc content of varieties and their damage susceptibility, infestation with mould and rots and sugar losses after storage, and 3) the environmental stability of the marc content of varieties. For the storage experiments, 10 varieties were grown at 8 sites in Germany, the Netherlands, Belgium and Sweden in 2015, 2016. After harvest, roots were stored for 8 weeks under controlled conditions. To evaluate the environmental stability, the same 10 varieties were grown at 12 sites in D, NL, B, S and Moldova in 2015 and 11 sites in D, NL, B, S in 2016. The results demonstrate a marked effect of the site on the extent of root tip breakage and surface damages, on infestation with mould and rots and on storage losses (invert sugar content, sugar losses). A general pattern could be identified: in most cases, a higher marc content of varieties coincided with less damages and less infestation with mould and rots, resulting in lower sugar losses. With the exception of variety 1, the marc content provided an indication of the storability of the varieties. The marc content turned out to be a very stable variety trait. These results indicate possibilities for breeding and selection for higher marc content and presumed better storability.

1. Introduction

Sugar beet storage gains increasing importance as the processing campaigns of the sugar factories have been extended in Europe. During storage, part of the assimilated sugar stored in the beet is metabolized to maintain survival processes of the sugar beet plant (Klotz and Finger, 2004). Van Swaaij and Huijbregts (2010) found a significant genotypic variation in sugar losses during storage. In the study of Schnepel and Hoffmann (2016) the marc content, which comprises all insoluble cell wall compounds of the sugar beet root, turned out to be closely related to the infestation with mould and rots after storage and finally to sugar losses of the genotypes. It was suggested that the marc content of sugar beet could perhaps serve as an indirect trait, which could be determined at harvest and which could provide a valuable indication about the storability of sugar beet varieties.

In the study of Schnepel and Hoffmann (2016) genotypes, which were not commercially available, were included. The genotypes were chosen according to expected large differences in storability. Accordingly, information about the range of storage losses of commercial varieties are still missing. Furthermore, it has to be tested whether also for commercial varieties a lower marc content is related to higher infestation with mould and rots after storage and higher sugar losses during storage.

In addition, the growing site seems to affect the storability of sugar beet (Van Swaaij and Huijbregts, 2010; Schnepel and Hoffmann, 2014; Liebe and Varrelmann, 2016). However, it is not known how a site or a variety could be characterized for low storage losses. The factor analysis can be used to combine several sugar beet parameters of different varieties and sites to detect general patterns of storage losses.

When the marc content is intended to be included into the selection process as an indirect criterion for storability, information is needed about the stability of this trait in different environments. The marc content of sugar beet varieties is usually not determined, because the analysis is very time-consuming. Therefore, knowledge about the marc content of sugar beet is scarce and only few studies are published (Kenter and Hoffmann, 2009). The marc content is often closely related

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to the sugar content of varieties (Beiß, 1989; Hoffmann et al., 2005), because generally varieties with high sugar content have smaller, but more parenchymal cells and consequently a higher proportion of cell wall compounds. Loel et al. (2014) reported that the marc content of varieties has unintendedly declined during the breeding process of the past decades, so that it was significantly lower for new varieties compared to old varieties grown in the same environments. However, the response of various varieties in different environments has never been studied, so that information on the stability of the trait marc content is lacking.

This study thus aimed at identifying 1) general patterns for the relation between various parameters before and after storage to characterize varieties and growing sites for low storage losses, 2) the causal relationship between marc content of varieties and their infestation with mould and rots and sugar losses, and 3) the environmental stability of the marc content of varieties.

2. Material and methods

2.1. Varieties

Sugar beet (*Beta vulgaris* subsp. *vulgaris var. altissima*) varieties, already released commercially, were provided by the breeding companies KWS SAAT SA (Einbeck, Germany), Strube Research (Schlanstedt, Germany), Syngenta (Bad Salzuflen, Germany) and SESVanderHave (Tienen, Belgium). They were chosen according to a particularly high or low marc content or to expected differences in storability. In total, ten varieties were included in the experiments.

2.2. Field trials

To test the marc content of the genotypes for their environmental stability (trial A), the ten varieties were grown in a completely randomized block design. The trials were laid out in four replicates at 12 locations in six row plots (8 across Germany, one in the Netherlands, one in Belgium, one in Sweden, one in Moldova), in 2015, and 11 locations (8 across Germany, one in the Netherlands, one in Belgium, one in Sweden), in 2016, in total 23 environments.

For the storage experiments (trial B, Table 1), the ten varieties were grown in a completely randomized block design with six replicates in six row plots at locations in Germany, the Netherlands, Belgium and Sweden in 2015 and in 2016, resp. (in total 8 environments, sites were different from trial A).

Plants were sown between end of March and mid of April, dependent on local soil and weather conditions. Plot area differed according to the local conditions, but was always more than 10 m^2. Plant population was about 100,000 plants ha^{-1}. Nutrient supply and control of pests and diseases of the trials was carried out in accordance with good agricultural practice. In October, the beets were machine harvested. Overtopped, severely damaged or fangy beets were discarded to minimize effects other than variety.

2.3. Storage trials

At each institute, storage trials were carried out with beets from their field trials (trial B). In addition, beet samples from all the trial sites were delivered and stored in Germany (storage at IfZ). As recommended by Legrand et al. (2016), from each field plot, two samples of approximately 20 kg roots in air permeable potato nets were made, one as reference before storage, the other one as storage sample. For details of storage conditions see Table 1. At IfZ, the samples were stored in a climate container at a constant temperature of 8 °C for about 8 weeks. To avoid effects of the position in the container and excessive dehydration in the upper layer, the samples were randomized and covered with an additional layer of beet bags. The relative humidity in the containers was around 98%.

2.4. Scoring of damages

The reference and the storage samples were scored on damages. From ten roots of each bag the diameter of the root tip breakage was determined with a gauge, the diameter of the topping cut was measured and the surface damage was scored (0 = none, 1 = low, 2 = medium: abrasions, 3 = severe damage: abrasions and breakage).

2.5. Scoring mould and rots

The proportion of beet surface infested with pathogens (visible mycelium and root rots) was visually scored after storage and prior to washing. Ten roots per bag were scored for the pathogen infestation of the root surface (0 = none, 1 = low, 2 = medium, 3 = severe infestation).

2.6. Analysis

Roots were weighted before and after washing, and soil tare (the soil adhering to the roots) was calculated from the difference between the weight before and after washing. Homogeneous beet brei was prepared and subsequently rapidly frozen and stored at −26 °C until analysis. Before the analysis, the brei was clarified with 0.3% aluminium sulphate solution. Sugar concentration was determined polarimetrically using an automated beet laboratory system (Venema Installations, Eemshaven, The Netherlands) and in accordance with ICUMSA method procedure (ICUMSA, 1994). The invert sugar (sum of glucose and fructose) content was calculated from the glucose content of the brei samples, using the conversion factor as described by Vermeulen (2015). The glucose content was determined using an immobilized enzyme biosensor (Firma Dr. Müller, Freital, Germany) and in accordance with ICUMSA method procedure (ICUMSA, 2017). Marc, which summarizes all insoluble cell wall compounds, was determined in beet brei from the reference samples. In the beet brei, the soluble components were successively removed with hot water, which was repeated four times. In the last step the insoluble residues were washed with aceton, then dried at 105 °C to constant weight (Reinefeld and Schneider, 1983). All beet

Table 1
Trial sites in the countries D, NL, B, and S in 2015 and 2016 for the storage experiments (trial B).

Country	Year	Latitude N	Longitude E	Soil texture	Storage conditions	Thermal time[a] (°C days)
D	2015	51.472	9.909	silty loam	climate container, 8 °C	520
D	2016	51.644	9.897	silty loam	climate container, 8 °C	476
NL	2015	52.539	5.565	loam	storage hall, ambient temperature	560
NL	2016	52.544	5.547	loam	storage hall, ambient temperatue	497
B	2015	50.378	4.161	loam	storage hall ambient temperature	475
B	2016	50.547	4.354	loam	storage hall ambient temperature	490
S	2015	55.683	13.114	clay	storage room, 12 °C	621
S	2016	55.685	13.116	clay	storage room, 12 °C	694

[a] Thermal time: number of days x mean daily temperature.