2. Haploidy in sugar beet (*Beta vulgaris* L.)

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1. Introduction

The cultivated beet is a biennial member of the Chenopodiaceae. It is bred for high yield of extractable sugar (sugar beet) or for high yield of roots with good feed value (fodderbeet). At the end of the first growing season, the thickened fleshy roots can be harvested and utilized. In the second year, after cold treatment (vernalization) in the field or in cold storage, the compressed stem will elongate into a 1–2 m tall inflorescence with numerous small petalless flowers in an open panicle.

While old beet cultivars were multigerm, having 3–5 seeds per cluster, modern cultivars are usually monogerm, since commercial seed is mainly harvested on genetically monogerm plants. Furthermore, these varieties are 100% hybrids due to the introduction of cytoplasmic male sterility (CMS). This makes sugar beet breeding rather complex. The breeder has to maintain two main programmes. Firstly, the monogerm programme, where monogerm, male-sterile, diploid CMS lines and their corresponding maintainer lines (OT) are inbred through 3–4 generations to create more or less homozygous lines with fixed traits. Due to inbreeding depression inbred CMS lines are crossed to unrelated OT lines to make single-cross lines (SX) with good seed-plant characteristics. Secondly, the selected single-crosses are then crossed to selected diploid or tetraploid, multigerm lines from the pollinator programmes. Diploid or triploid hybrids are harvested on the single-crosses as potential cultivars.

Because sugar beet is one of the major crops in the world, the effort


on biotechnological developments in sugar beet has been rather intensive. Although it has been regarded as a relatively recalcitrant species in in vitro culture, regeneration of whole plants from callus, suspension culture and protoplasts has been reported, but the ability to regenerate seems to be genotype dependent. Genetic manipulation, using the well-established Agrobacterium tumefaciens technique for transfer of genes into sugar beet, is now routine in many laboratories (Fry et al., 1990; Lindsay and Gallois, 1990; D’Halluin et al., 1992). Thus, many in vitro techniques are presently in use successfully on sugar beet. However, one technique has failed: the haploidization of sugar beet via anther or microspore culture.

To obtain haploid (2n = x = 9) or doubled haploid sugar beets in quantities attractive for breeding purposes, it has been necessary to use the more labour intensive ovule culture techniques. The relatively high cost per doubled haploid (DH) sugar beet line produced by this technique is one of the main reasons for the rather low demand so far for doubled haploid techniques in breeding of sugar beet. But as the technique becomes more efficient and reliable it is foreseen that use of doubled haploid plants will be a natural choice in future breeding of sugar beet, either directly as 100% inbred components in the breeding programme or as an efficient method for fixing of desirable genes. Furthermore (doubled) haploids are valuable in RFLP mapping, as tools for diverse genetic studies, and in the study of reproductive biology and in biotechnological research.

Haploid sugar beets can be obtained by in vivo or in vitro techniques. Although in vivo induction of haploid sugar beets has been known for a long time (Levan, 1945; Kruse, 1963; Bosemark, 1971; Yüce, 1973; Seman, 1983), the relatively new haploid induction technique in vitro has become the method of choice for routine production. If chromosome doubling is needed, this can be done either by treatment of the haploid plantlets with a suitable chromosome doubling agent such as colchicine or alternatively by treatment in the early stage of in vitro culture (Hansen et al., 1994).

In this paper, we intend to review the current status, problems, and prospects of utilizing haploids in improving sugar beet. We have paid most attention to the ovule culture technique for haploid production. Due to the inter-company competitive nature of the methods for (doubled) haploid production in sugar beet, results from the often intensive work done or sponsored by breeding companies has usually only been presented as posters or as oral presentations and the actual protocols used by the companies are not always available.

2. Haploid production by in vivo techniques

Haploids obtained spontaneously during sexual reproduction in sugar beet are rare (Levan, 1945; Kruse, 1963; Bosemark, 1971; Yüce, 1973; Seman, 1983). The first haploid sugar beet was found after colchicine treatment of