1. Introduction

The genus *Allium* contains some of the most important vegetables and spices used throughout the world including onion, leek, garlic, and shallot. Additional *Allium* species are cultivated more regionally including chives (*A. schoenoprasum* L.), Chinese chives (*A. tuberosum* Rottl. ex Spr. and *A. ramosum* L.), rakkyo (*A. chinense* G. Don), and *A. hookeri* Thw. In 1987, the cultivation of onions and shallots comprised 1.25 million ha in developing and 0.5 million ha in developed countries (Currah and Proctor, 1990).

*A. cepa* L. is, undoubtedly, the most important species within the genus. According to the type of reproduction and use, the forms of this species can be divided into two groups: the common onions, which are propagated mainly by seed, and the *aggregatum* group (including shallots and potato onions) which are primarily propagated vegetatively (Hanelt, 1990). Due to this difference and the sterilities that often occur among the vegetatively propagated types, breeding is more advanced in common onion than in shallot.

The main breeding objectives for *A. cepa* concern quality (dry matter content, flavour, bulb colour and shape), development (specific daylength dependency, uniformity of ripening, and storability), and pest resistance. The latter includes resistance to several viruses: shallot latent virus and onion.

yellow dwarf virus (Walkey, 1990); fungi: white rot (Sclerotium cepivorum Berk.), downy mildew (Peronospora destructor [Berk.] Casp.), pink root rot (Phoma terrestris Hansen), Botrytis and Fusarium diseases; and insects: onion thrips (Thrips tabaci Lind.) and onion fly [Delia antiqua (Meigen)] (Dowker, 1990). A large gene pool of related wild species, possessing useful characters such as disease, frost or salt resistance, will gain increasing importance as biotechnological methods become available to facilitate gene transfer.

*A. cepa* is a predominantly outbreeding species due to strong protrandry. Pollination from other flowers of the same inflorescence is, however, possible because of a flowering gradient within the inflorescence. A high degree of heterozygosity exists because of these features. Traditional cultivars are heterogeneous populations providing sufficient background for selection. In less developed countries, onion breeding has been concentrated on selection of superior types from land races. In advanced countries, however, breeding programmes to derive hybrids using male sterility have been underway for some time. Heterosis resulting from crosses of homozygous inbreds is expected to hasten the realization of breeding goals. However, inbreeding depression has been reported to diminish the effect of hybrid breeding by influencing the production of homozygous parental lines. Rapid progress in the production of homozygous material for hybrid breeding programs can be made by using DH (doubled haploid) lines derived from haploid plants.

The main pathways for haploid induction are androgenesis (discovered by Guha and Maheshwari, 1964), gynogenesis (first description by San Noeum, 1976), and chromosome elimination [exemplified by the so-called bulbosum technique in *Hordeum* (Symko, 1969)]. Of these methods, only gynogenesis has been used effectively to produce haploid and doubled haploid onion plants, although there have been attempts to employ all of the above techniques.

2. Haploid induction via androgenesis

Despite considerable effort in anther culture of onion, it remains among the androgenetically recalcitrant species. Keller (1990a) cultured a total of 98,027 anthers on 25 different culture media but observed no androgenic development. Campion et al. (1984) observed nuclear cleavage in onion anther cultures but obtained no further development. The only development obtained in these studies was callus formation from the filaments (Fig. 1). In *A. altaicum* Pall., *A. fistulosum* L. and its hybrids with onion or leek, a high frequency of callus (up to 41.7% in *A. altaicum*) developed. Most callus occurred in media with equimolar (1 μM) concentrations of 2,4-D and BA (Keller, 1990a). An experiment to determine the effect of sucrose in the more reactive species, *A. porrum* L., revealed an optimum of callus formation at a relatively high (10%) sucrose level (Keller, 1992a).