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# The effect of 1-methylcyclopropene (1-MCP) on the physical and biochemical characteristics of onion cv. SS1 bulbs during storage

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**Abstract**

There is a paucity of information on the role of ethylene in onion bulb dormancy, and the available literature is conflicting. Onion cv. SS1 bulbs were treated with 1 $\mu l l^{-1}$ 1-MCP for 24 h at 20 °C and then stored at 4, 12 or 20 °C. Sprout growth was reduced in onions treated with 1-MCP and stored at 4 or 12 °C, but not when stored at 20 °C. Greater concentrations of sucrose, glucose and fructose were measured in 1-MCP treated bulbs stored at 12 °C as compared with untreated bulbs. Dry weight was also maintained in onions treated with 1-MCP. Abscisic acid (ABA) concentration before storage has previously been shown to be correlated with storage life, but there were no differences in the ABA concentration between 1-MCP treated and untreated bulbs. It appeared that 1-MCP reduced the rate of carbon utilisation. The mechanism by which this occurred is unknown although it is unlikely to be mediated by ABA.


*Keywords:* Abscisic acid; *Allium cepa* L.; Ethylene; Non-structural carbohydrates; Sprouting

## 1. Introduction

The storage life of onion bulbs is limited by the rate of elongation of the sprout inside the bulb. Maleic hydrazide, a synthetic sprout suppressant, is used to extend storage life. However, pressure from retailers and consumers to reduce or eliminate chemical residues in food is increasing, and therefore other methods to prolong storage life of bulbs are necessary, particularly for low-pungency cultivars such as SS1 that command a premium price, but have an inherently short storage life. A better understanding of the mechanisms involved in onion bulb dormancy would assist in the identification of potential targets for manipulation of storage life.

During over-winter storage of onion bulbs a gradual change in the relative composition of plant growth regulators occurs as the concentrations of growth inhibitors drop and those of growth promoters rise. The concentrations of inhibitors in bulbs with internal signs of sprouting are low when compared with the levels in non-sprouting or fully sprouted bulbs (Thomas, 1969). The variation in the concentration of gibberellins, cytokinins, auxins (Thomas, 1969, Thomas and Isenberg, 1972) and abscisic acid (ABA) (Chope et al., 2006), have been measured in stored onion bulbs. The peaks in growth substances are thought to be responsible for floral initiation under cold conditions (first gibberellin peak), cell multiplication (cytokinins) and the initiation of sprout growth (auxins). Onion bulb ABA concentration decreased during postharvest storage and onset of sprouting occurred at minimal ABA concentration (Chope et al., 2006).

Ethylene is also a plant growth regulator and is clearly fundamental to the postharvest physiology of many fresh produce types; however, the literature on the role of ethylene in onion bulb dormancy and storage life is far from comprehensive. There are conflicting reports on how ethylene affects onion storage life. The observation that onion cv. Elba Globe bulbs produced ethylene in much greater amounts (actual amounts not specified) at the end of dormancy than at the beginning (Abdel-Rahman and Isenberg, 1974) suggests that ethylene may have a role in sprouting. In contrast, Benkeblia

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and Selselet-Attou (1999) found little variation in ethylene production (range of 4.4–4.6 nmol $kg^{-1}$ $h^{-1}$) of onion cv. Rouge Amposta bulbs during 6 months storage at 18 °C and 70% RH. The dichotomy between these findings implies that production of ethylene by onion bulbs is likely to be cultivar dependent and that further investigation is required.

Ethylene perception can be blocked using 1-methylcyclopropene (1-MCP), which binds to ethylene binding proteins, thereby preventing ethylene from exerting its effects (Blankenship and Dole, 2003). 1-MCP is approved for food use in several countries, and has been tested on a range of climacteric and non-climacteric fresh produce, and cut flowers (Watkins and Miller, 2005; Watkins, 2006).

The aim of this experiment was to investigate the effect of 1-MCP on sprouting in onions cv. SS1, in order to assess the potential of 1-MCP as a treatment to delay sprout growth and/or as a tool to explore the role of ethylene in onion dormancy. The changes in onion bulb ABA concentration, as well as characteristics associated with quality (pyruvate, total soluble solids (TSS) and firmness) and the changes in non-structural carbohydrates (NSC) were measured.

## 2. Materials and methods

### 2.1. Plant material and storage regime

Onions cv. SS1 were grown from seeds drilled at a rate of 18 seeds $m^{-2}$ in March 2004 at Warwick HRI (Warks, UK). Pesticides were applied according to commercial practice. Maleic hydrazide was not applied. Plants were harvested at 80–90% tops down in early September. Onions were placed into 25 kg nets and loaded into bin driers. Hot air (ca. 30 °C) was blown through the onions for 9 days, followed by ambient air for a further 2 weeks (as per commercial practice; Chope et al., 2006). The dry aerial parts and roots were removed, and any diseased or damaged bulbs discarded prior to storage.

### 2.2. 1-MCP application

Onion bulbs were placed in cardboard trays inside rigid polypropylene fumigation chambers (88 cm × 59 cm × 59 cm). A 1-MCP evolving solution was prepared by adding 1.80 g SmartFresh (Rohm and Haas, PA, USA) to a 50 ml conical flask, and sealing with a SubaSeal (Fisher, Leics, UK), then 20 ml distilled water at 50 °C was injected into the flask through the seal (Dauny et al., 2003). The flask was immediately opened and placed in the chamber with the onion bulbs. The chamber was closed with a moat of water providing an air-tight seal. This process achieved initial concentrations of 0.962 μl $l^{-1}$ 1-MCP within the chamber. The chamber was kept sealed for 24 h at 20 °C.

### 2.3. 1-MCP quantification

The concentration of 1-MCP was quantified by flame ionisation gas chromatography (GC model 8340, EL980 FID and DP800 integrator, Carlo Erba Instruments, Herts, UK). Oven and detector temperatures were set at 100 and 250 °C, respectively. The 2 m × 4 mm stainless steel column was packed with Chromosorb PAW mesh range 80–100, liquid phase OV1701 30% loading (Jones Chromatography, Mid Glamorgan, UK). The carrier gas was helium (British Oxygen Company (BOC) Gases, Surrey, UK) at a flow rate of 38 ml $min^{-1}$. Calibration of 1-MCP was carried out against 10.7 μl $l^{-1}$ isobutane (BOC) (Sisler and Serek, 1997). The concentration of 1-MCP was 0.962 μl $l^{-1}$ after 2 h.

### 2.4. Storage conditions and sampling regime

Following exposure to 1-MCP, bulbs were removed from the boxes and stored at three temperatures; 4, 12 and 20 °C. Bulbs were removed for sampling before 1-MCP treatment (baseline (day 0), $n = 5$). Samples were taken after 53 and 109 days from the 4 °C storage treatment, after 26, 39 and 53 days from the 12 °C storage treatment and after 7, 26 and 39 days from the 20 °C storage treatment. For all samples after the baseline, $n = 5$ for untreated bulbs and $n = 10$ for 1-MCP treated bulbs.

### 2.5. Sample preparation

Samples were prepared according to Chope et al. (2006). Briefly, juice was expressed from an equatorial slice using a hand-operated press (Randle and Bussard, 1993) then frozen at −20 °C for pyruvate and TSS measurements. A section cut from each bulb was snap-frozen in liquid nitrogen and kept at −40 °C until the sample was lyophilised (Edwards Super Modulo, Sussex, UK) in preparation for NSC and ABA assays.

### 2.6. Physical analyses

The following physical assessments were made: sprout growth, firmness and dry weight. Sprout growth was recorded and expressed as the height of the first appearing green leaves inside the bulb as a percentage of bulb height; firmness was measured using an Instron Series IX materials testing machine (Instron, Bucks, UK) and dry weight was measured on lyophilised samples according to Chope et al. (2006).

### 2.7. Biochemical analyses

The following biochemical measurements were made: ABA concentration, pyruvate concentration, concentration of NSC and TSS. ABA was measured by radioimmunoassay, pyruvate by absorbance assay, fructan by enzyme assay and TSS by the use of a hand-held refractometer according to Chope et al. (2006). Fructose, glucose and sucrose were measured using HPLC as described below.

#### 2.7.1. Extraction of non-structural carbohydrates

Fructose, sucrose and glucose were extracted from onion bulbs according to O'Donoghue et al. (2004) with slight