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Prolonging the storability of bedding plants

June 2006

Confidential

Hans de Wild
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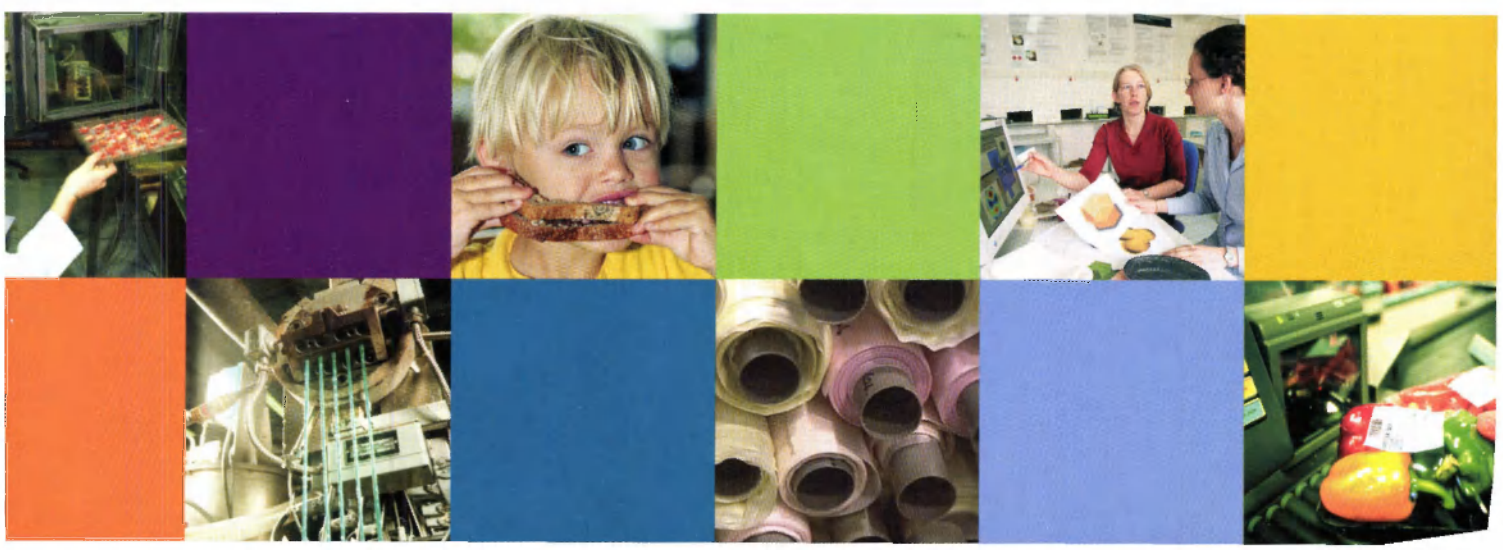
Report 668



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Colophon

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Summary

This report describes experiments with storage of bedding plants. The research was carried out by AFSG (Wageningen University and Research Centre) for Syngenta Seeds BV. It started with a first orientation on prolonging the storability of the most important species with controlled atmosphere (CA) storage. Based on results of this research, a next experiment was dedicated to packaging.

Several CA conditions were tested at 4 and 10 °C. In total 14 species were exposed to various combinations of low O_2 and high CO_2 during 7, 14 and 21 days. Tested species were: *Ageratum, Bacopa, Bidens, Calibrachoa, Diascia, Euryops, Fuchsia, Lobelia, Osteospermum, Petunia, Sanvitalia, Scaevola, Verbena,* and *Vinca.* After the following growth period in the greenhouse, quality was judged based on general impression, leaf colour, rooting performance, and rot.
CA storage was not successful for prolonging the storage period of bedding plants. CA storage showed no improvement compared to storage at normal atmosphere. High CO_2 concentrations (6%, 12%) were harmful for the tested products. The tested species were robust regarding temperature. Only *Ageratum* appeared to be sensitive: 4°C storage was detrimental compared to 10 °C. For the other species no quality differences between the two storage temperatures were observed.

The package experiment was carried out with 6 species in 5 packages and compared to standard package. Tested species were: *Ageratum, Impatiens, Lavendula, Osteospermum, Scaevola,* and *Verbena.* The package experiment showed that there was only little accumulation of CO_2 and ethylene in the standard packages. CO_2 and ethylene adsorbers were effective in removing these gases. This effect is expected to become more important at higher gas accumulations which for instance can occur at (temporary) higher temperatures.

Contents

1 Introduction

Bedding plants like verbena, osteospermum, lobelia and petunia are produced by Syngenta in Kenia or Israël. They are transported by plane to The Netherlands and planted within ±48 hours after arrival. A longer storage time is not used due to the risk of quality loss. This short storage time in combination with season peaks requires a large quantity of mother plants.
Prolonging the storage time in The Netherlands would give opportunities to save costs in production and distribution.

The research as described in this report started with a first orientation on prolonging the storability of the most important species with controlled atmosphere (CA) storage. Based on results of this research, a next experiment was dedicated to packaging. It was tested whether quality protective packaging can create an added value for Syngenta in their current air freight based distribution system.

2 Material and methods

2.1 Controlled Atmosphere (CA)

In the CA flow-through system of AFSG, various species were exposed to the following conditions:

- Temperature: **4 °C**
- Oxygen(%)-Carbondioxide (%): 2-0, 5-0, 2-6, 5-6, 10-6, 2-12, 5-12, 10-12, 21-0.
- Replicates: 2 (CA containers).
- References: storage room S&G and storage room AFSG. Replicates: 1.
- Storage time: 7, 14, and 21 days.
- Number of cuttings per experimental unit: 2 bags with 56 cuttings.

To investigate the effects of CA at suboptimal temperatures, some gas treatments were also performed at a higher temperature:

- Temperature: **10 °C**
- Oxygen(%)-Carbondioxide (%): 2-0, 5-6, 5-12, 10-6, 10-12, 21-0.
- Replicates: 1 (CA container).
- References: storage room S&G and storage room AFSG. Replicates: 1.
- Storage time: 7 and 14 days.
- Number of cuttings per experimental unit: 2 bags with 56 cuttings.

The following products were investigated:
Ageratum, Bacopa, Bidens, Calibrachoa, Diascia, Euryops, Fuchsia, Lobelia, Osteospermum, Petunia, Sanvitalia, Scaevola, Verbena, and Vinca. The origin of these products was Kenia or Israël (Petunia and Calibrachoa).

After storage, the products were transported to S&G and planted. After a growth period the plants were judged by S&G on the following quality parameters:

- Rooting performance (scale 1-5; 1 = quick and/or uniform, 5 = slow and/or heterogeneous.
- Rot (scale 1-5: 1 = no rotting, 2 = 0-25% rotting, 3 = 25-50% rotting, 4 = 50-75% rotting, 5=75-100% rotting)
- Leaf colour (scale 1-5; 1 = dark green, 5 = yellow)
- General impression (scale 1-5; 1 = very good, 5 = very bad)

Statistical analyses

Effects of various gas conditions compared to references were analysed statistically. First it was analysed whether there is interaction between gas condition and storage time (using ANOVA at a significance level of 95%). Only in case of interaction, the effect of gas condition is analysed for each storage time separately. In case of no interaction, the averages of 3 storage times are

compared. Comparisons between each treatment with reference were made using the least significant differences between means (LSD) at a significance level of 95%.

2.2 Testing of different packages

Because the CA storage experiment did not give any indication that this method could improve storage of bedding plants, the following experiment was directed to a search for alternative protective packaging.
The test was carried out with 6 species of cuttings:

- Impatiens (JN225, AN9183, Kokomo petit scarlet)
- Scaevola (SQ058, AN9901, Whirlwind blue)
- Verbena (VR116, AN9973, Tukana scarlet)
- Osteospermum (OS105, AN9793, Jamboana white improved)
- Ageratum (AG075, AN9381, Artist basso blue)
- Lavendula (LV016, AN0242, hidcote blue)

These products are selected due to different sensitiveness to climate conditions:

- Impatiens is sensitive to enhanced ethylene concentrations
- Scaevola is sensitive to CO_2 and Botrytis
- Verbena is sensitive to dehydration
- Osteospermum is sensitive to Botrytis
- Ageratum is sensitive in all aspects
- Herbs: essential oils may induce ethylene related problems or protect against Botrytis.

Species were also selected because of their market importance (commercial arguments).

Packages were developed to control: dehydration, carbon dioxide, ethylene and *botrytis* spores inside packages. Results from the past indicated that these factors determine the final quality of the cuttings.

Packaging variants were:

1. Standard PE-film as currently used by Syngenta: pe-bag, thickness 10µm, sealed, no perforations
2. PE-bag: thickness 15 µm humidified gas adsorber sachets (C_2H_4 and CO_2) enclosed, sealed, no perforations
3. PA (polyamide bag): Brand: Xtend thickness 15µm, sealed, 4 macro-perforations
4. OPP film/ anti fog layer: 30µm, sealed, 4 macro perforations
5. OPP film/ anti fog (p-plus concept), micro-perforated, sealed, anti botrytis pad and humidified gas adsorbers enclosed
6. Bio degradable plastic bag: PLA (poly lactic acid) 4 macro perforations

The motivation for the selection of materials was as follows:

Ad 1: standard packaging: polyethylene film thickness 10μm

PE (LDPE) has a very low water vapour transmission rate and a relative high permeation rate for CO_2 and a 3 fold lower diffusion rate for oxygen (O_2). Ethylene transmission through PE is unknown but might be relatively high due to the very thin film. Thickness is linear related to gas diffusion: 2 fold thicker means 2 fold less permeation. Anti fog properties of PE are usually very poor: AFSG considers this as a disadvantage with respect to Botrytis growth.

The costs of PE bags are very low. There are many suppliers that offer PE bags.

Ad 2: PE bag (15 μm with moisturized gas adsorbers prepacked in sachets)

The opinion of the project team is that quality may be improved by lowering the ethylene concentration in the packages. On the other hand dehydration must be avoided as has been noticed in previous experiments. This can be achieved via closed and sealed packages. The disadvantage is that respiratory CO_2 will accumulate. So not only ethylene (C_2H_4) but also CO_2 must be adsorbed out of the package.

Summarizing: this bag will prevent the cuttings to dehydrate. Adsorbers also adsorb moist from the cuttings. Adsorbers will be humidified to prevent this. Adsorbers are less effective when moisturized. In this experiment no activities are planned for optimal design of the sachets i.e. the complete package. Sachets with gas adsorbers will cost more than the costs of PE bags only. The price depends on quantities.

Ad 3: Xtend film (PA)

This PA (polyamide) bags have a high oxygen permeation rate and the WVTR of PA is higher than of PE. The producer claims excellent results with several commodities. Permeation is necessary to avoid too high CO_2 and C_2H_4 concentrations in the sealed bags. High gas permeation of the polymer with a minimum of perforation holes might give a good atmosphere for cuttings.

Cost price of the patent protected Xtend bags is higher than PE, but much lower if sachets with gas adsorbers can be avoided.

Ad 4: OPP/anti fog film with perforation

Compared to PE, OPP has much improvement of anti-fog characteristics. This may be beneficial to minimise Botrytis. Perforation is necessary to avoid undesirable altered gas conditions (CO_2 and C_2H_4).

Ad 5: OPP film with micro-perforations and sachets

Moisturized gas adsorbers and an anti-Botrytis pad (prototype) will be enclosed in the package. This is the most complicated package system. Price will be the highest of the chosen variants due to the use of different active components. Saturated doses of active components will be used.

Ad 6: PLA bags (BIO)

PLA (poly lactic acid) is a new biodegradable polymer. The commonly used raw material for this polymer is fermented maize starch. The characteristics with respect to gas and moisture are different from PE, OPP, and PA. Still perforations are necessary to avoid excessive CO_2 and/or C_2H_4-concentrations. The price of PLA bags is double the price of OPP bags, but is decreasing.

All bags were sized: 30*24cm. Exceptions were the Xtend bags. These are only available in the size: 30*19 cm. Standard sized bags contain 128 cuttings, Xtend was filled with 25% less cuttings.

Storage

All products were stored at 4°C, only Ageratum was stored at 10°C due to the limited cold tolerance of this species. Storage time was 7 and 14 days. Product was stored in 5 replicates per storage time.

Handling

To prevent negative effects from extra handling in this test compared to normal handling procedures the cuttings in the standard package were also repacked. A not repacked reference was stored in AFSG storage rooms.

Gas measurements and weight loss

Gas measurements were performed on O_2, CO_2 and C_2H_4 concentrations inside the packages, mainly for packages with low perforation. This was not done for package 5 with anti-botrytis pad to avoid possible damage of the gas chromatograph. Weight loss measurements were done for Ageratum and Verbena.

Statistical analyses

Effects of various gas conditions compared to the reference (repacked) were analysed statistically. First it was analysed whether there is interaction between package type and storage time (using ANOVA at a significance level of 95%). Only in case of interaction, the effect of package is analysed for each storage time separately. In case of no interaction, the averages of 2 storage times are compared. Comparisons between each package with the reference were made using the least significant differences between means (LSD) at a significance level of 95%.

3 Results Controlled Atmosphere

3.1 Effect of CA at 4 °C

Explanation of tables:

The tables below show the results per species.

The score for the reference is given between brackets (1-5 with 1=best). This makes it possible to compare storage times. This score is the mean of reference AFSG and reference S&G, which scores in general were similar.

Gas conditions are given for instance as 2-0 (2% O_2, 0% CO_2).

Effects of various gas conditions compared to references were analysed statistically. First it was analysed whether there is interaction between gas condition and storage time (using ANOVA at a significance level of 95%). Only in case of interaction, the effect of gas condition is analysed for each storage time separately. In case of no interaction, the averages of 3 storage times are compared.

Comparisons between each treatment with reference were made using the least significant differences between means (LSD) at a significance level of 95%.

Within each table cell the treatment can be compared with the reference:

Red = score of this treatment is significant worse compared to reference

Green = score of this treatment is a significant improvement compared to reference

Yellow = score of this treatment is equal to reference

General results:

No improvement was found by using CA. There was no positive effect of low O_2 while high CO_2 (6%, 12%) must be avoided.

Ageratum 4 °C

General remark: Cuttings after 14 days storage at 2-12 (2% O_2 and 12% CO_2), 5-12 and 10-12 were partly wilted.

*General impression : interaction gas*storage time:* $LSD_{0.05} = 0.81$
*Leafcolour : interaction gas*storage time:* $LSD_{0.05} = 0.95$
*Rooting : interaction gas*storage time:* $LSD_{0.05} = 1.08$
*Rotting : interaction gas*storage time:* $LSD_{0.05} = 1.07$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	**Ref *(4.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 **21-0**	**Ref *(4.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(4.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	**Ref *(5.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(5.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(5.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(5.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Bacopa 4 °C

General impression : *no interaction gas*storage time:* $LSD_{0.05} = 0.76$
Leafcolour : *no effect of gas treatment. Only effect of storage time.*
Rooting : *no effect of gas treatment. Only effect of storage time.*
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.91$

Storage time	General impression	Leafcolour	Rooting	Rotting
7 + 14 +21	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0			
7	Ref ***(1.0)***	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)***	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(2.5)***	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Bidens 4 °C

General remark: Cuttings after 21 days storage at 2-12 (2% O_2 and 12% CO_2), and 10-12 looked already bad at moment of sticking.

General impression : *interaction gas*storage time:* $LSD_{0.05} = 1.47$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 1.07$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 1.73$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 1.32$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(2.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Calibrachoa 4 °C

General remark after 21 days storage at various treatments (also reference): older leaves are partly turned and curled.

General impression : *interaction gas*storage time:* $LSD_{0.05} = 0.77$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 0.69$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 0.51$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.66$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Diascia 4 °C

General impression : *no effect of gas, no effect of storage time*
Leafcolour : *interaction gas*storage time: $LSD_{0.05} = 0.44$*
Rooting : *no effect of gas treatment. Only effect of storage time*
Rotting : *no effect of gas, no effect of storage time*

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Euryops 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 1.07$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 1.14$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 1.02$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.93$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Fuchsia 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 0.75$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 0.82$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 0.85$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.77$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Lobelia 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 0.87$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 0.55$
Rooting : *effect of gas treatment* ($LSD_{0.05} = 0.50$). *Also effect of storage time.*
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.36$

Storage time	General impression	Leafcolour	Rooting	Rotting
Mean of 7 + 14 +21			Ref ***(1.4)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)***	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)***	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)***	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Several trays of Lobelia were given the remark 'intermediate with respect to plant growth' or 'rooted cuttings relatively compact' (shown by grey color in the columns in the following table). As these remarks were given for several gas conditions, and differed between the storage periods, no conclusion can be drawn about influence of gas condition

Storage time	Intermediate with respect to plant growth Grey = yes	Rooted cuttings relatively compact Grey = yes
7	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Osteospermum 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 0.84$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 0.48$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 0.59$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.82$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Petunia 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 0.29$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 0.23$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 0.26$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.35$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Sanvitalia 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 0.95$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 1.03$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 1.03$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 1.03$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(2.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Several trays of Sanvitalia were given the remark 'intermediate with respect to plant growth' or 'rooted cuttings relatively compact' (shown by grey color in the columns in next table). The last remark was given for all conditions with 12% CO_2 after 7 days storage. Although 12% CO_2 did not affect other quality assessments after 7 days storage (general impression, leaf colour, rooting, or rot), there is potential drawback of applying this CO_2 concentration as shown by the quality assessments after 14 and 21 days storage (table above).

Storage time	Intermediate with respect to plant growth Grey = yes	Rooted cuttings relatively compact Grey = yes
7	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Scaevola 4 °C

General impression : *Effect of gas ($LSD_{0.05}$ = 0.70) and effect of storage time*
Leafcolour : *Effect of gas ($LSD_{0.05}$ = 0.67) and effect of storage time*
Rooting : *interaction gas*storage time: $LSD_{0.05}$ = 1.19*
Rotting : *Effect of gas ($LSD_{0.05}$ = 0.69) and effect of storage time*

Storage time	General impression	Leafcolour	Rooting	Rotting
Mean of 7 + 14 +21	Ref ***(3.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0		Ref ***(3.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
7	Ref ***(1.8)***	Ref ***(1.0)***	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(2.0)***
14	Ref ***(3.8)***	Ref ***(2.5)***	Ref ***(3.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(3.0)***
21	Ref ***(5.0)***	Ref ***(4.0)***	Ref ***(5.0)*** 2-0, 2-6, 2-12 5-0, 5-6 5-12 10-6, 10-12 21-0	Ref ***(5.0)***

Verbena 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 1.52$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 1.37$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 1.13$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 1.57$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(2.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.8)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	**Ref *(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

Vinca 4 °C

General impression : *interaction gas*storage time:* $LSD_{0.05} = 0.77$
Leafcolour : *interaction gas*storage time:* $LSD_{0.05} = 0.48$
Rooting : *interaction gas*storage time:* $LSD_{0.05} = 0.80$
Rotting : *interaction gas*storage time:* $LSD_{0.05} = 0.59$

Storage time	General impression	Leafcolour	Rooting	Rotting
7	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
14	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.0)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0
21	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.5)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0	Ref ***(1.3)*** 2-0, 2-6, 2-12 5-0, 5-6, 5-12 10-6, 10-12 21-0

3.2 Effect of CA at 10 °C

All species except Lobelia were also tested at 10 °C.
There were no replicates performed. For statistical analyses the various species can be taken as replicate or the storage time can be taken as replicate. The first analysis showed that there was no improvement of CA compared to the reference (table 1). High CO_2 must be avoided. The second analysis showed that especially Sanvitalia was sensitive to high CO_2 (table 2).

Table 1. The effect of gas on 'general impression' (mean of all species). Within each row the effect of gas condition was compared to the reference ($LSD_{0.05}$ = 0.48). Red = score of this gas condition is significant worse compared to reference S&G.

	Treatment (O_2-CO_2)							
	Ref							Ref
Storage time	S&G	2-0	5-6	5-12	10-6	10-12	21-0	A&F
7 days storage	1.12	1.23	1.04	1.12	1.21	1.20	1.15	1.14
14 days storage	1.46	1.43	1.69	1.3	1.62	1.5	1.65	1.99

Table 2. The effect of gas on "general impression' (mean of 2 storage times). Within row the effect of gas condition was compared to the reference ($LSD_{0.05}$ = 1.47). Red = score of this gas condition is significant worse compared to reference S&G.

	Treatment (O_2-CO_2)							
	Ref							Ref
Species	S&G	2-0	5-6	5-12	10-6	10-12	21-0	A&F
Ageratum	2.0	1.5	2.0	2.3	2.3	3.0	1.8	1.5
Bacopa	1.3	1.8	1.0	1.8	1.5	2.0	2.0	2.0
Bidens	1.0	1.0	1.0	1.3	1.3	1.5	1.0	1.2
Calibrachoa	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
Diascia	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Euryops	1.0	1.0	1.0	1.5	1.0	1.5	1.3	1.0
Fuchsia	1.0	1.4	1.0	1.0	0.9	0.6	1.0	1.1
Osteospermum	1.5	1.0	2.0	2.8	1.0	2.0	1.8	1.5
Petunia	1.0	1.0	1.0	1.3	1.0	1.5	1.5	2.0
Sanvitalia	1.0	1.0	2.0	2.5	1.5	2.5	1.0	1.5
Scaevola	2.5	3.3	2.8	2.8	3.5	3.8	3.0	3.3
Verbena	1.0	1.3	1.0	2.3	1.5	2.0	1.0	2.0
Vinca	1.5	1.4	1.0	1.5	1.0	1.6	1.0	1.4

3.3 Comparison between 4 °C and 10 °C at reference conditions

It was analysed per species whether temperature is important at **reference** conditions. The mean of 7 and 14 days storage was taken to analyse the effect of temperature on 'general impression' (Table 3). Only for Ageratum an effect of temperature was found: storage at 10 °C was better than at 4 °C.

Table 3. Comparison between 4 and 10 °C for score on 'general impression'.
Red = score of this temperature is significant worse compared to other temperature.

	Treatment					
Ras	**Ref.S&G**		**21-0**		**Ref.A&F**	
	4°C	**10°C**	**4°C**	**10°C**	**4°C**	**10°C**
Ageratum	3.0	2.0	2.9	1.8	2.1	1.5
Bacopa	1.0	1.3	1.8	2.0	1.0	2.0
Bidens	1.0	1.0	1.3	1.0	1.0	0.9
Calibrachoa	1.0	1.0	1.0	1.0	1.0	1.0
Diascia	1.0	1.0	1.0	1.0	1.5	1.0
Euryops	1.0	1.0	1.1	1.3	1.0	1.0
Fuchsia	1.0	1.0	1.0	1.0	1.0	1.4
Osteospermum	1.0	1.5	1.9	1.8	1.0	1.5
Petunia	1.0	1.0	1.0	1.5	1.0	2.0
Sanvitalia	1.0	1.0	1.6	1.0	1.8	1.5
Scaevola	3.0	2.5	2.4	3.0	2.5	3.3
Verbena	1.0	1.0	1.1	1.0	1.0	2.0
Vinca	1.0	1.5	1.1	1.0	1.0	1.5

3.4 Comparison between 4 °C and 10 °C at total range of tested conditions

It was analysed per species whether temperature is important at the **range of all tested conditions** (O_2%-CO_2%: 2-0, 5-6, 5-12, 10-6, 10-12, 21-0). The mean of all conditions and of 7 and 14 days storage was taken.
At standard air conditions, storage at 4 °C will be better than storage at 10 °C because of inhibition of product activity (except for *Ageratum*). When gas conditions are not standard, storage at 10 °C can be better than at 4 °C (table 4). Probably the inhibition of product activity is to severe if low temperature (4 °C) is combined with CA, while at 10 °C this is not the case.

Table 4. Comparison between 4 and 10 °C (mean of all tested conditions and all storage times).
Red = score of this temperature is significant worse compared to other temperature.

Species	General impression		Leaf colour		Rooting_ performance		Rotting	
	4°C	10 °C	4°C	10 °C	4°C	10 °C	4°C	10 °C
Ageratum	3.3	2	3.1	2.2	3.0	1.6	3.1	1.8
Bacopa	1.5	1.7	1.0	1.0	1.4	1.5	1.0	1.0
Bidens	1.7	1.1	1.6	1.5	1.3	1.0	1.6	1.2
Calibrachoa	1	1.1	1.5	1.5	1.0	1.0	1.0	1.0
Diascia	1.1	1	1.0	1.0	1.0	1.0	1.0	1.0
Euryops	1.7	1.2	1.5	1.0	1.7	1.3	1.8	1.3
Fuchsia	1.1	1	1.0	1.0	1.0	1.0	1.1	1.0
Osteospermum	1.7	1.7	1.2	1.3	1.4	1.4	1.7	1.6
Petunia	1.2	1.3	1.6	1.6	1.0	1.1	1.0	1.1
Sanvitalia	2.1	1.7	1.7	1.2	1.8	1.4	1.7	1.5
Scaevola	2.9	3.1	2.0	2.1	2.3	2.5	2.8	2.8
Verbena	1.8	1.5	1.5	1.3	1.4	1.3	1.4	1.3
Vinca	1.3	1.3	1.1	1.3	1.2	1.3	1.3	1.4

4 Results of packages

4.1 Gas conditions inside packages

Ageratum and Scaevola showed accumulation of ethylene in the standard packages (table 5). All species showed accumulation of CO_2 although small. As expected, the accumulation of these gases is less in packages with higher perforation (PA, OPP and bio). Gases were not measured for the package with anti-botrytis pad to avoid possible damage of the gas chromatograph. The used CO_2 and C_2H_4 adsorbers were effective in preventing accumulation of these gases.

Table 5. Measured gas concentrations in packages during the experiment (mean of 2-5 replicates).

	Standard, Not repacked	**Standard, repacked**	**PE, humidified C_2H_4 en CO_2 pads**	**PA**	**OPP**	**OPP, humidified pads+anti-Botrytis**	**Bio**
Verbena (4 days storage / 7 days storage)							
O_2 (%)	19 / 21	19 / 21	19 / 21				
CO_2 (%)	0.08 / 0.14	0.12 / 0.18	0 / 0				
C_2H_4 (ppb)	<10 / <10	<10 / <10	<10 / <10				
Ageratum (4 days storage / 7 days storage)							
O_2 (%)	19 / 20	19 / 20	17 / 20	19	19		19
CO_2 (%)	0.24 / 0.19	0.13 / 0.23	0.00 / 0.02	0.11	0.09		0.10
C_2H_4 (ppb)	14 / 58	115 / 50	10 / < 10				
Impatiens (4 days storage / 7 days storage)							
O_2 (%)	/21		/19	/21			
CO_2 (%)	/0.11		/0.07	/0.13			
C_2H_4 (ppb)	/<10		/<10	/<10			
Lavendula (/ 7 days storage)							
O_2 (%)	/ 21	/ 21	/ 21				
CO_2 (%)	/ 0.20	/ 0.14	/ 0.02				
C_2H_4 (ppb)	/ <10	/ <10	/ <10				
Osteospermum (4 days storage / 7 days storage)							
O_2 (%)	19 / 21	18 / 20	18 /19	/21	/21		/21
CO_2 (%)	0.32 / 0.30	0.39 / 0.43	0.02 / 0.05	/0.16	/0.11		/0.14
C_2H_4 (ppb)	<10 / <10	<10 / 19	<10 / <10	/ <10	/<10		/<10
Scaevola (/ 7 days storage)							
O_2 (%)	/ 20	/ 20	/ 21				
CO_2 (%)	/ 0.31	/ 0.25	/ 0.04				
C_2H_4 (ppb)	/ 45	/ 28	/ < 10				

4.2 Verbena

The standard package had low CO_2 and ethylene concentrations (table 5). No improvement of quality was found with alternative packages (table 6). Verbena is sensitive to dehydration, but weight loss in the standard package was relatively low.

Table 6. ***Verbena****. Quality assessments after storage in various packages followed by a growth period in the greenhouse. Data in bold lines were tested for significant differences compared with 'standard, repacked'. Red = significant worse than standard package.*

Days storage	Standard, Not repacked	Standard, repacked	PE, humidified C2H4 en CO2 pads	PA	OPP	OPP, humidified C2H4 en CO2 pads + anti-Botrytis pad	bio
General impression: effect of treatment ($LSD_{0.05}$ = 0.49)							
7 days	1.6	1.0	1.0	1.4	1.4	2.6	1.2
14 days	1.0	1.6	1.4	1.6	1.8	2.8	2.0
Mean	**1.3**	**1.3**	**1.2**	**1.5**	**1.6**	**2.7**	**1.6**
Leaf colour: effect of treatment ($LSD_{0.05}$ = 0.39)							
7 days	1.4	1.6	1.2	1.6	1.2	2.0	1.4
14 days	1.0	1.8	1.4	1.4	1.8	2.0	2.0
Mean	**1.2**	**1.7**	**1.3**	**1.5**	**1.5**	**2.0**	**1.7**
Rooting: effect of treatment ($LSD_{0.05}$ = 0.46)							
7 days	1.4	1.0	1.2	1.6	1.4	1.8	1.0
14 days	1.6	1.6	1.4	1.8	2.0	2.6	2.0
Mean	**1.5**	**1.3**	**1.3**	**1.7**	**1.7**	**2.2**	**1.5**
Rot: effect of treatment ($LSD_{0.05}$ = 0.42)							
7 days	1.4	1.0	1.2	1.2	1.0	2.0	1.2
14 days	1.0	1.2	1.4	1.4	1.4	2.6	1.6
Mean	**1.2**	**1.1**	**1.3**	**1.3**	**1.2**	**2.3**	**1.4**
% Weight loss: interaction storage*treatment ($LSD_{0.05}$ = 3.5)							
7 days	**2.1**	**1.4**	**2.4**	**1.4**	**1.4**	**0.7**	**7.1**
14 days	**4.6**	**2.9**	**-0.6**	**16.2**	**1.0**	**1.5**	**16.0**
Mean	3.4	2.2	0.9	12.3	1.2	9.1	11.5

4.3 Ageratum

Ageratum showed little CO_2 and moderate ethylene accumulation in the standard package, which could have negatively affected rooting after 7 days storage (table 7). Accumulation of gases was prevented in the PE package with humidified C_2H_4 and CO_2 pads (table 5), where rooting was better. Also the higher perforation in other packages could have lead to better rooting. For other quality parameters, no improvement of quality was found with alternative packages (table 7).

Table 7. ***Ageratum.*** *Quality assessments after storage in various packages followed by a growth period in the greenhouse. Data in bold lines were tested for significant differences compared with 'standard, repacked'. Green=significant better than standard package, Red = significant worse than standard package.*

Days storage	Standard, Not repacked	Standard, repacked	PE, humidified C2H4 en CO2 pads	PA	OPP	OPP, humidified C2H4 en CO2 pads + anti-Botrytis pad	bio
General impression: effect of treatment ($LSD_{0.05}$ = 0.36)							
7	1.0	1.0	1.0	1.0	1.0	1.6	1.0
14	1.0	1.4	1.8	1.6	1.2	2.6	1.8
Mean	**1.0**	**1.2**	**1.4**	**1.3**	**1.1**	**2.1**	**1.4**
Leaf colour: interaction storage*treatment ($LSD_{0.05}$ = 0.32)							
7 days	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
14 days	**1.0**	**1.0**	**1.4**	**1.0**	**1.4**	**1.4**	**1.8**
Mean	1.0	1.0	1.2	1.0	1.2	1.2	1.5
Rooting: interaction storage*treatment ($LSD_{0.05}$ = 0.57)							
7 days	**1.8**	**1.4**	**1.0**	**1.0**	**1.8**	**1.4**	**1.2**
14 days	**1.4**	**1.4**	**2.0**	**1.8**	**1.6**	**2.2**	**1.6**
Mean	1.6	1.4	1.5	1.4	1.7	1.8	1.4
Rot: effect of treatment ($LSD_{0.05}$ = 0.28)							
7 days	1.0	1.0	1.0	1.0	1.0	1.6	1.2
14 days	1.0	1.2	1.4	1.4	1.2	2.2	1.0
Mean	**1.0**	**1.0**	**1.1**	**1.2**	**1.1**	**1.9**	**1.1**
% Weight loss: interaction storage*treatment ($LSD_{0.05}$ = 2.8)							
7 days	**1.1**	**1.9**	**2.4**	**9.1**	**1.5**	**7.7**	**11.5**
14 days	**2.3**	**3.5**	**5.3**	**22.7**	**5.9**	**9.3**	**23.2**
Mean	1.7	2.7	3.9	15.9	3.7	8.5	17.3

4.4 Impatiens

Impatiens shows rotting problems with storage at 4 °C for a longer period. This has influenced the rooting results for a big part. Therefore these trays were only judged for 'general impression'. No improvement of quality was found with alternative packages (table 8).

Table 8. ***Impatiens.*** *Quality assessments after storage in various packages followed by a growth period in the greenhouse.*

Days storage	Standard, Not repacked	Standard, repacked	PE, humidified C2H4 en CO2 pads	PA	OPP	OPP, humidified C2H4 en CO2 pads + anti-Botrytis pad	bio
General impression: No effect of treatment							
7	3.6		3.4	4.6	3.3	3.0	3.8

4.5 Lavendula

Accumulation of CO_2 and ethylene in the standard package was very small (table 5). No improvement of quality was found with alternative packages (table 9).

Table 9. ***Lavendula.*** *Quality assessments after storage in various packages followed by a growth period in the greenhouse. Data in bold lines were tested for significant differences compared with 'standard, repacked'. Red = significant worse than standard package.*

Days storage	Standard, Not repacked	Standard, repacked	PE, humidified C2H4 en CO2 pads	PA	OPP	OPP, humidified C2H4 en CO2 pads + anti-Botrytis pad	bio
General impression: interaction storage*treatment ($LSD_{0.05}$ = 0.65)							
7 days	2.0	2.0	2.2	2.4	2.4		1.8
14 days	2.4	2.8	3.4	3.4	2.2		3.0
Mean	2.2	2.4	2.8	2.9	2.3	4.3	2.4
Leaf colour: interaction storage*treatment ($LSD_{0.05}$ = 0.35)							
7 days	1.0	1.0		1.2			1.2
14 days	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Mean	1.5	1.5	1.7	1.6	1.8	2.0	1.6
Rooting: interaction storage*treatment ($LSD_{0.05}$ = 0.54)							
7 days	1.0	1.3		1.6	1.8		1.0
14 days	2.0	2.0			2.0		2.4
Mean	1.5	1.6	2.6	2.5	1.9	3.5	1.7
Rot: interaction storage*treatment ($LSD_{0.05}$ = 0.57)							
7 days	2.0	2.0	2.2	2.0	2.0		1.8
14 days	2.2	2.0			1.8		
Mean	2.1	2.0	2.7	2.5	1.9	3.5	2.2

4.6 Osteospermum

There was a small accumulation of CO_2 in the standard package, but accumulation could be limited by using CO_2 pads or more perforations (table 5). No improvement was found with alternative packages (table 10). The repackaging improved the quality (compare 'standard, not repacked' with 'standard, repacked'). Refreshment of air seems to be advantageous and may also be achieved by macro-perforations in the standard package. This is also indicated by the results with PA and OPP packages with macro-perforations. However, comparison between standard package and standard package + macro-perforations requires further tests (in practice) to find out whether indeed improvement can be made.

Table 10. ***Osteospermum.*** *Quality assessments after storage in various packages followed by a growth period in the greenhouse. Data in bold lines were tested for significant differences compared with 'standard, repacked'. Red = significant worse than standard package. Green = significant improvement.*

Days storage	Standard, Not repacked	Standard, repacked	PE, humidified C2H4 en CO2 pads	PA	OPP	OPP, humidified C2H4 en CO2 pads + anti-Botrytis pad	bio
General impression: Effect treatment ($LSD_{0.05}$ = 0.61)							
7 days	2.4	1.6	1.8	1.6	2.4	2.8	2.6
14 days	2.0	2.6	2.2	1.8	1.6	3.4	2.6
Mean	**2.2**	**2.1**	**2.0**	**1.7**	**2.0**	**2.1**	**2.6**
Leaf colour: Effect treatment ($LSD_{0.05}$ = 0.37)							
7 days	2.0	1.0	1.0	1.4	1.4	1.8	2.0
14 days	1.6	1.4	1.4	1.0	1.2	1.8	1.6
Mean	**1.8**	**1.2**	**1.2**	**1.2**	**1.3**	**1.8**	**1.8**
Rooting: Effect treatment ($LSD_{0.05}$ = 0.50)							
7 days	2.0	1.6	1.4	1.6	2.4	2.6	2.0
14 days	1.8	1.8	1.8	1.8	1.4	2.6	2.0
Mean	**1.9**	**1.7**	**1.6**	**1.7**	**1.9**	**2.6**	**2.0**
Rot: Effect treatment ($LSD_{0.05}$ = 0.49)							
7 days	2.2	1.4	1.8	1.8	2.2	2.8	2.4
14 days	2.2	2.0	1.8	1.6	1.8	2.8	2.0
Mean	**2.2**	**1.7**	**1.8**	**1.7**	**2.0**	**2.8**	**2.2**

4.7 Scaevola

Scaevola showed little CO_2 and moderate ethylene accumulation in the standard package (table 5). This was limited in the PE package with humidified C_2H_4 and CO_2 pads. However, no improvement of quality was found with alternative packages (table 11).

Table 11. ***Scaevola.*** *Quality assessments after storage in various packages followed by a growing period in the greenhouse. Data in bold lines were tested for significant differences compared with 'standard, repacked'. Red = significant worse than standard package.*

Days storage	Standard, Not repacked	Standard, repacked	PE, humidified C2H4 en CO2 pads	PA	OPP	OPP, humidified C2H4 en CO2 pads + anti-Botrytis pad	bio
General impression: Effect treatment ($LSD_{0.05}$ = 0.48)							
7	1.4	1.2	2.0	1.4	1.0	2.6	1.4
14	1.8	2.4	2.4	2.6	2.0	3.2	2.2
Mean	**1.6**	**1.8**	**2.2**	**2.0**	**1.5**		**1.8**
Leaf colour: No effect of treatment							
7	**1.4**	**1.2**	**1.8**	**1.4**	**1.6**	**1.8**	**1.0**
14	**1.0**	**1.2**	**1.0**	**1.2**	**1.2**	**1.4**	**1.4**
Mean	**1.2**	**1.2**	**1.4**	**1.3**	**1.4**	**1.6**	**1.2**
Rooting: Effect treatment ($LSD_{0.05}$ = 0.33)							
7	1.6	2.0	2.0	1.8	1.4	2.2	2.0
14	2.0	2.0	2.0	2.4	2.0	2.6	2.4
Mean	**1.8**	**2.0**	**2.0**	**2.1**	**1.7**	**2.4**	**2.2**
Rot: Effect treatment ($LSD_{0.05}$ = 0.34)							
7	1.0	1.0	1.2	1.0	1.0	1.6	1.0
14	1.3	1.8	1.8	1.8	1.8	2.4	1.8
Mean	**1.1**	**1.4**	**1.5**	**1.4**	**1.4**		**1.4**

5 Conclusions

CA (controlled atmosphere) storage was not successful for prolonging the storage period of bedding plants. CA storage showed no improvement compared to storage at normal atmosphere. High CO_2 concentrations (6%, 12%) were harmful for the tested products. The tested species were robust regarding temperature. Only *Ageratum* appeared to be sensitive: 4°C storage was detrimental compared to 10 °C. For the other species no quality differences between both storage temperatures were observed.

The standard (current) package is a good package at the tested constant low temperature. The package experiment showed that there was only little accumulation of CO_2 and ethylene in the standard packages. CO_2 and ethylene pads were effective in removing these gases. This adsorbing effect is expected to become more important at higher gas accumulations which for instance can occur at (temporary) higher temperatures.
It is recommended to invest in temperature management (constant low temperature) rather than in packaging. If temperature management is not adequate, a cost risk analysis for possible use of packages (with adsorbers or with more perforation) becomes useful.