fertilizers which correspond more specifically to rhododendron needs.

3. Further research into the use of chemical agents which induce bud production.

4. New cultivars which possess desirable characteristics of form and of plentiful flowers should be selected.

STORAGE OF UNROOTED CONIFEROUS CUTTINGS

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INTRODUCTION

Seasonal peaks of work-load are the main reason why German nursery managers have shifted the period for propagating conifers by cuttings into the winter months, November, and December (4). But as a result, more heating and more intensive phytosanitary treatments are necessary. Rising energy costs led to the idea of collecting the cuttings in November, preparing them for insertion and then storing them up until March. The main spring selling season in German nurseries starts in March. For this reason collecting and preparing the cuttings has to be done earlier, if possible in early winter.

Suitable storage conditions must be used to avoid a significant reduction of the rooting capacity. That is why:

- — water losses of the cuttings have to be kept to a minimum (13).
- — the spread of pathogenic fungi has to be avoided (10), and
- — respiration has to be kept low, especially if a definite amount of food reserves is necessary for quick and sufficient rooting (13,19).

All this is possible with storage at low temperature and high humidity and perhaps controlled atmosphere (CA) is advantageous (2,5).

Cuttings of conifers cultivated in Germany have the advantage of being resistant to low temperatures if collected at the proper time of the year, but these cuttings have the disadvantage of not being storage organs which can accumulate food reserves in larger amounts. Thus, the storage temperature for coniferous cuttings might be below freezing, and this seems to be of some significance because diminishing the consumption of reserve material is very important.

Storing bare-rooted woody plants is a technique well known by nurserymen (3,15,20). The publications on cold storage of unrooted cuttings primarily concern herbaceous or deciduous plants (6,16); only a few refer to coniferous cuttings (7,11,12,14). However, conditions necessary for successful winter storage of cuttings of ornamental conifers have not yet been investigated.

MATERIALS AND METHODS

Based on the experience of storing bare-rooted woody plants and fruits as well as on the results of a pilot test, experiments were carried out to investigate the influence of the storage at +2°C, 0°C, −2°C, and −4°C. Furthermore, for each temperature normal atmosphere was compared with controlled atmosphere (CA) of 3% CO_2 and 3% O_2.

Cuttings were packed in perforated polyethylene bags and stored in jacketed cold stores. In a separate experiment the effect of a jacketed cold store was compared with the effect of a conventional directly cooled store, whereby in the latter case the cuttings were covered with plastic film.

The influence of cutting preparation and bundling (25 cuttings/bundle) was investigated. The cuttings were prepared by stripping-off the needles from the lower stem portion and applying a rooting-powder and fungicide mixture (0.4% IBA, and captan) to the base of the cuttings.

After storing for four months (November 15 to March 15), the cuttings were inserted in a medium of peat and sand (1:1, v/v) and placed in a plastic tunnel in an unheated greenhouse.

The experiments were carried out on ten different species and cultivars of ornamental conifers (see Figures 3 and 4).

The final criterion in judging a suitable storage method is the quantity of saleable liners — not just the rooting percentage. Prolonging the production period cannot be accepted. Cuttings could only grow to a saleable liner in the usual time if they had formed a good root system by the middle of the growing season. That is why the counting of well-rooted cuttings was done in early July.

Percentages were transformed with the angular transformation and data subjected to standard analysis of variance procedures, LSD $\alpha = 0.05$ Tukey-Test.

RESULTS

Cuttings stored best if they were not bundled (Figure 1). Species that are sensitive to fungal attack showed grey mold infection if bundled, even at temperatures of −2°C; they also rooted less well. The temperature within the tightly bundled plant material was at least 3°C higher than in the surrounding storage atmosphere. A more uniform distribution of the temperature was possible if cuttings were not stored in large compacted batches but in loose lots.

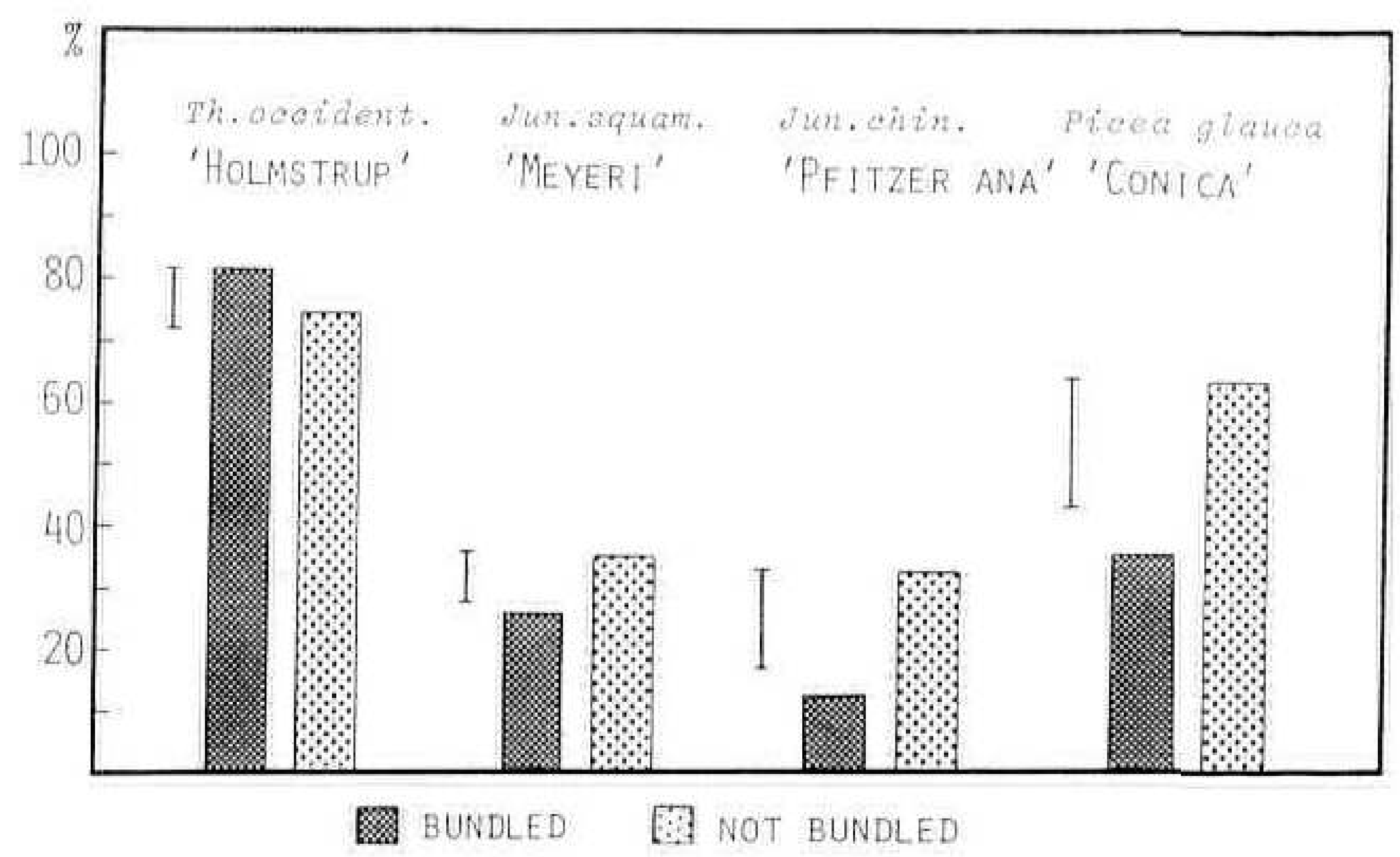

Figure 1. Influence of bundling on the rooting percentage of stored cuttings.

Depending on the cooling system employed, different ways of protecting against desiccation were necessary. In a jacketed cold store cuttings needed no additional covering with plastic film, but good results were achieved after packing them in perforated polyethylene bags. On the other hand, perforated poly-bags and additional wrapping with plastic were necessary in a storage room with direct cooling. In both cases rooting results were similar.

Preparing the cuttings ready for insertion was possible before storage as there was no significant influence upon results. Only for species susceptible to fungal attack was the fungicide treatment advantageous.

Controlled atmosphere storage had a significant influence on the rooting capacity of only four of the tested species (Figure 2). Presented are the summarized results of the differ-

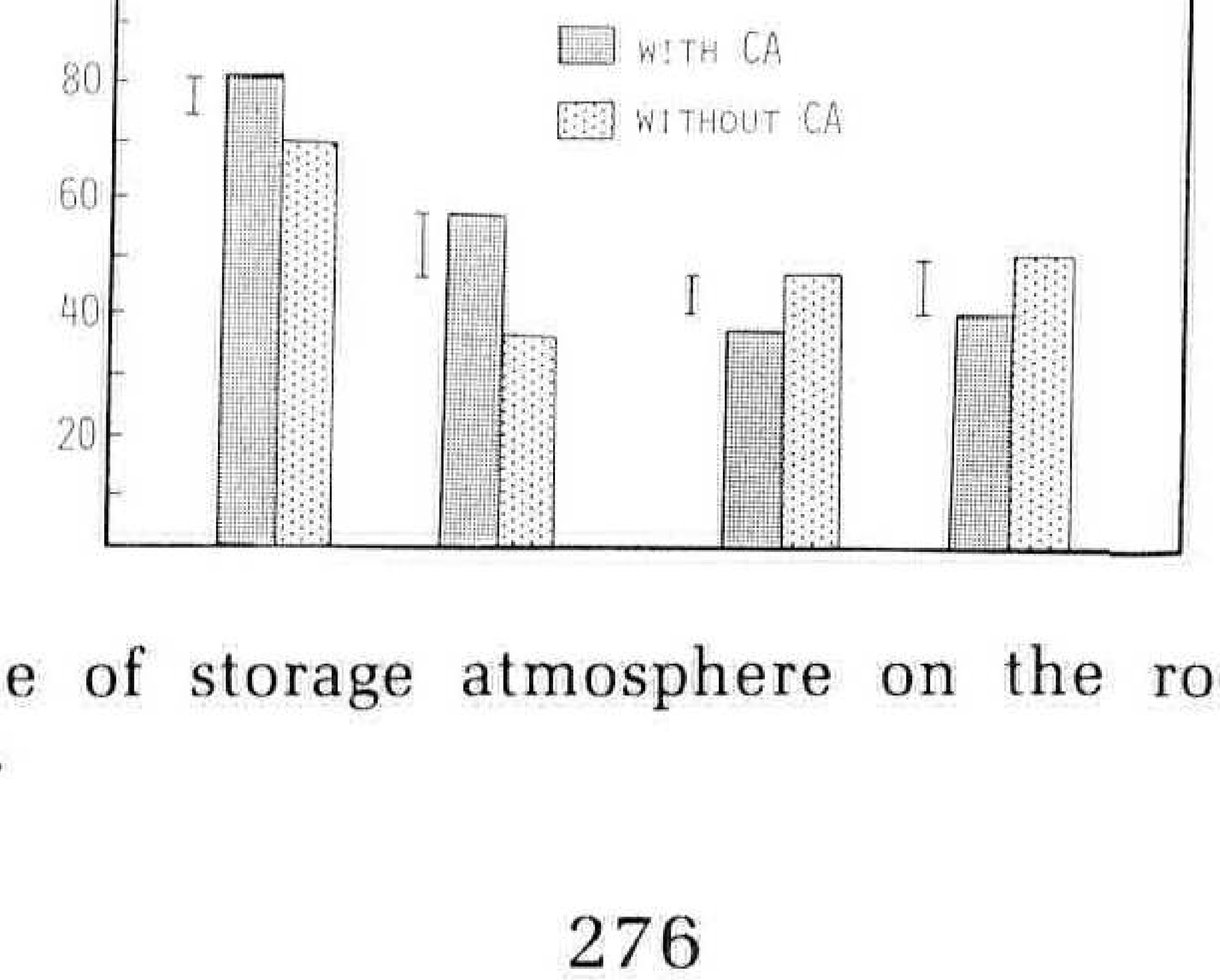

Figure 2. Influence of storage atmosphere on the rooting percentage of cuttings.

ent storage temperatures. *Chamaecyparis pisifera* 'Boulevard' and *Picea glauca* 'Conica' were in a better condition if stored in CA rather than in a normal atmosphere. This was particularly so at temperatures above freezing. On the other hand, *Juniperus* rooted better after storage in normal atmosphere, especially at temperatures below freezing. Of more significance was the influence of the storage temperatures (Figures 3 and 4).

Figure 3 shows those species that gave the same results in different years. Storage at +2°C proved to be least satisfactory, the rooting percentages were significantly lower than at the other temperatures. But the optimal storage temperature was different from one species to another: 2°C below freezing for *Chamaecyparis lawsoniana* cultivars; −4°C to 0°C for *C. pisifera*, and freezing point for *Thuja*.

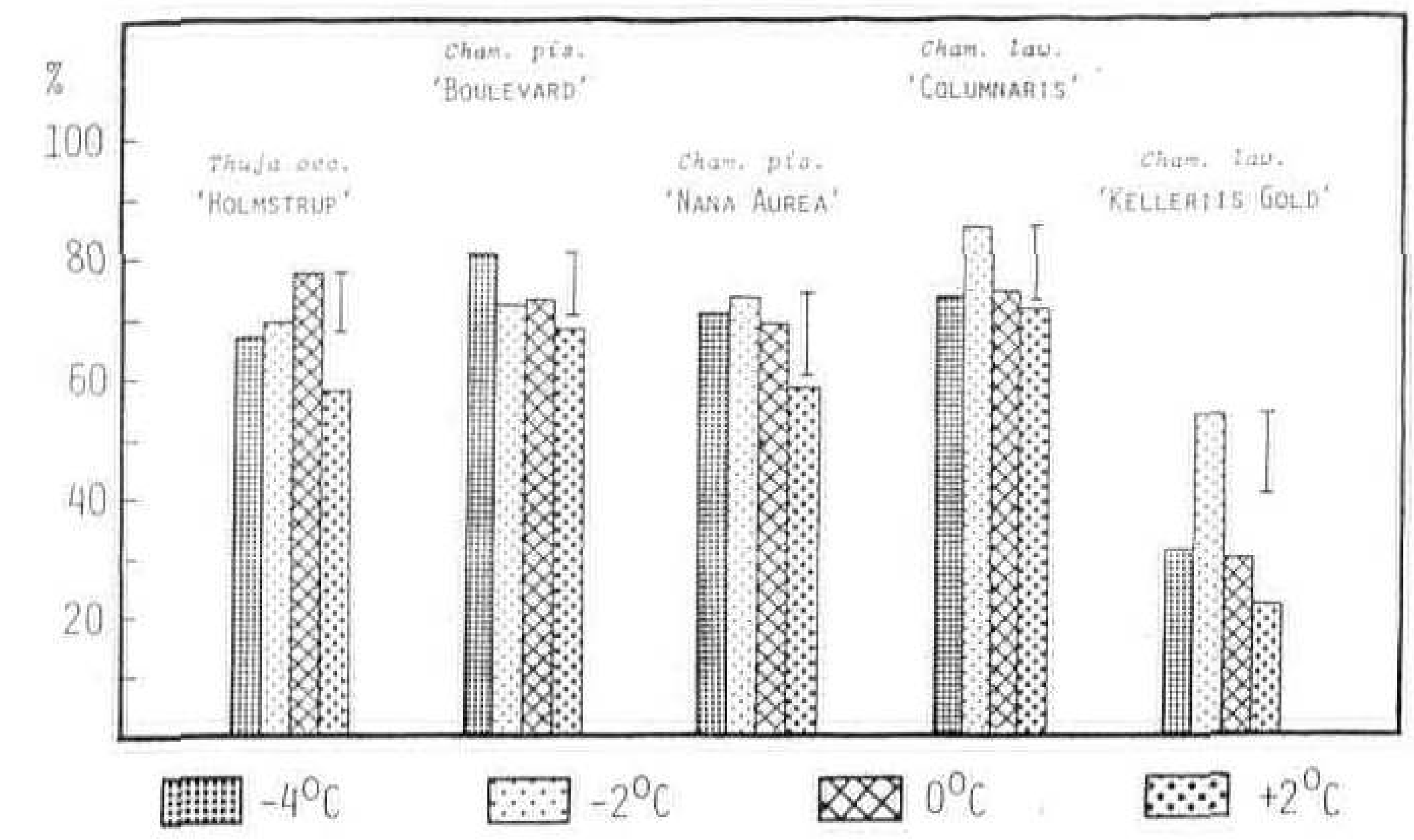

Figure 3. Influence of different storage temperatures on the rooting percentage of cuttings. *Left to right. Thuja occidentalis* 'Holmstrup', *Chamaecyparis pisifera* 'Boulevard', *C. pisifera* 'Nana Aurea', *C. lawsoniana* 'Columnaris', *C. lawsoniana* 'Kelleriis Gold'.

For the other species (Figure 4) a temperature of +2°C did not lead to the highest rooting percentages either, it often led to the lowest ones. Which temperature was best depended not only on the species but also on the year. From 1981 to 1982 the optimal temperature shifted to the next lower temperature for *Taxus* and *Picea* and to higher temperatures for *Juniperus*.

DISCUSSION AND CONCLUSION

Conditions for successful storage could be found for nearly all species. The optimal storage condition resulted in the same propagation success as the conventional propagation method.

Water losses were about the same regardless of storage conditions, and the cuttings could be kept healthy during storage. On the other hand, consumption of reserve materials was different. Fats and proteins were not used as food reserves. As expected, the temperature of +2°C led to the highest reduction

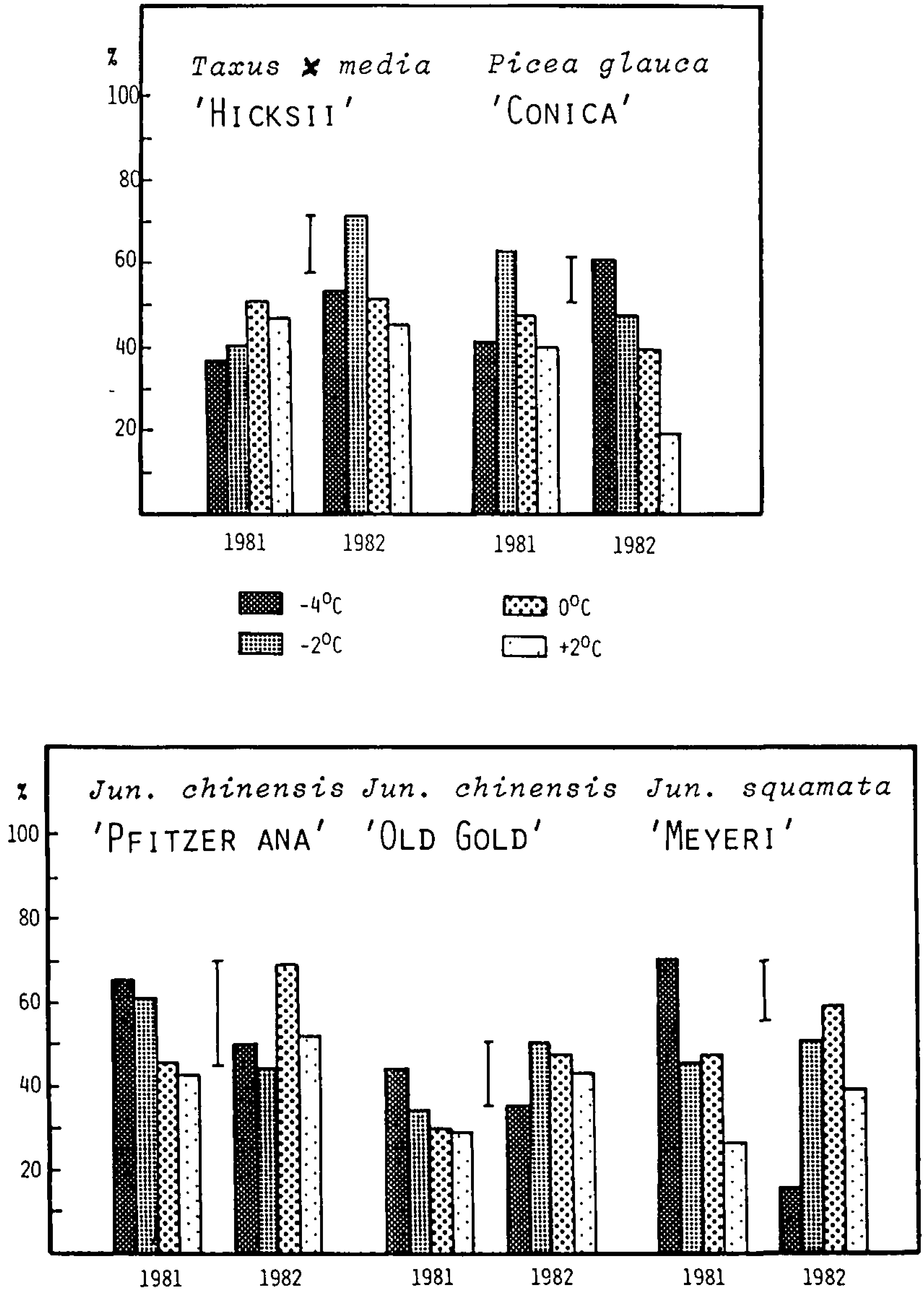

Figure 4. Influence of different storage temperatures on the rooting percentage of cuttings in 1981 and 1982.

of sugars and other carbohydrates; the lower the storage temperature the smaller the carbohydrate losses through respiration (1).

There are two advantages in diminishing losses of reserve materials:

- — keeping the right amount of carbohydrates for successful rooting (13,18,19).
- — maintaining the frost hardiness of the cuttings (8,9).

Depending on which reason is more important and depending on the initial content of food reserves and frost protecting materials, the optimal storage temperature varies for the different species and years.

Plant parts which are not storage organs can hardly be enriched with high amounts of photosynthetic products. Thus, stored cuttings may run out of their food reserves and probably start to exhaust their frost protecting materials (17). Then rooting may be reduced as a result of frost damage, especially if cuttings are stored at −4°C. This could mean that cuttings which have developed a greater frost hardiness on the stock plant are most suitable for successful storage. The plant cells contain a much higher percentage of various organic compounds which can be used for frost protection and for metabolic processes during storage and rooting. The weather conditions which are favourable for building up frost hardiness are not present at the same time every year. Cuttings collected at a fixed date may not have the same degree of hardiness.

A temperature of 0°C to −2°C was the most satisfactory for all species on an average over the different years.

Taking into account the results of this investigation a propagation programme can be proposed for the production of winter-propagated conifers:

- — Collection of cuttings only after the build-up of sufficient frost hardiness (after a period of low temperature).
- — Preparation of cuttings ready for insertion.
- — Packing loose in perforated poly-bags.
- — Storage in a jacketed cold store or polyethylene wrapped in a conventional cold store.
- — Storage temperature of −1°C to −3°C.
- — Storage period up to 4 months.
- — Keeping the tops of the cuttings cold and the buds quiescent during rooting.
- — A good phytosanitary programme.
- — Potting from June to July.

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