Rhizome dormancy and shoot growth in myoga
(Zingiber mioga Roscoe)

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Accepted 12 August 1999

Abstract

After the senescence of above ground plant parts the rhizomes of myoga undergo a period of dormancy. The length of this dormancy period and the requirement for chilling to break dormancy are examined in this paper. Myoga rhizome segments were capable of initiating shoot growth 6 weeks after excision from a recently senesced dormant mother plant. A period of chilling was not required for shoot growth, but chilling at 4°C for 3 weeks immediately after excision resulted in shoot development in newly divided myoga rhizome segments which would otherwise not have sprouted until after a 6-week dormancy phase. Longer storage periods before planting and increased duration of chilling treatments decreased the variability in the sprouting response of rhizome segments. Chilling at 4°C for 2–4 weeks was the most effective treatment for promoting uniform sprout emergence and subsequent flower production. Shoot growth rate and the number of vegetative shoots produced by the rhizome was not affected by chilling treatments. Increasing the length of chilling, promoted earlier sprouting and flowering, but may have decreased the weight of the flower buds produced. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Dormancy; Chilling; Rhizome; Ginger; Myoga; Zingiber mioga; Sprouting

1. Introduction

Myoga (Zingiber mioga Roscoe) is a rhizomatous perennial plant endemic to Japan and is cultivated primarily for its edible flower buds. The immature flower

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buds, and to a lesser extent young shoots or pseudostems, are utilised in Japanese cooking as a fresh condiment or blanched vegetable (Nakamura, 1985). Myoga, or Japanese ginger, has recently been introduced into New Zealand (Follett, 1994) and Australia where its potential as a cultivated crop is being assessed. An understanding of the growth and development of the plant is required to develop appropriate cultural practices under the prevailing cool temperate climatic conditions.

Myoga displays a distinct periodicity of growth. Under natural conditions, myoga undergoes a period of dormancy or rest over the winter months. Growth commences as temperatures increase in spring. Pseudostems (vegetative shoots) grow from rhizomes in spring followed by a flush of flowers developing from the basal, underground section of pseudostems, in mid summer to early autumn. Rhizome growth commences during the later stages of flower development and under ideal growing conditions can lead to a 20-fold increase in plant weight in a single season. Foliage senescence and abscission is observed in late autumn, and rhizomes then enter a dormant or rest period.

Cultivation of myoga in Australia and New Zealand is undertaken using a raised 1.2 m wide bed system and the crop life expectancy is 3–5 years. Commercial propagation of myoga is through vegetative division of rhizomes during the dormant phase. The current practice for establishing the crop in the field is to plant pieces of the dormant rhizome that are approximately 25 cm long into well cultivated soil. However, there is limited information available on the optimal requirements for treating the rhizomes to break dormancy and induce maximum growth and flower production in the first season after planting. Palmer (1984) examined myoga production in New Zealand and found that in the absence of any preplanting treatment, only approximately half of the newly established plants produced flowers during the first year of growth. Maeda (1994) reported that chilling is required to break the dormancy of rhizomes and that increasing the duration of chilling treatments hastened the commencement of pseudostem growth. Douglas (1993) recommended that rhizomes should receive a preplant chilling treatment of 4°C for at least 6 weeks to produce optimum growth in the first season. Douglas and Follett (1992) reported that flowering was erratic and unpredictable in areas where insufficient winter chilling occurs. Temperatures from 2°C to 5°C are reported as being optimal for chilling (Maeda, 1994; Douglas, 1993; Nakamura, 1985), with the period required to effectively break the dormancy of rhizomes reported as 20 or more days (Nakamura, 1985), 6 weeks (Douglas, 1993) or greater than 60 days (Maeda, 1994).

Despite the apparent importance of chilling in overcoming dormancy of rhizomes and promoting the commencement of pseudostem growth, the physiological mechanisms involved have not been reported. Maeda (1994) observed that short photoperiods accelerated the progress towards the dormant
state while long photoperiods delayed the onset of dormancy. While the report of Maeda (1994) pointed to the importance of photoperiods, it was not possible to determine whether this was a true photoperiodic effect. In the same study it was demonstrated that the effect of chilling to overcome dormancy varied with the length of in-ground storage of the dormant rhizome, with a higher percentage of rhizomes observed to break dormancy after longer storage periods. On the basis of these observations, Maeda (1994) concluded that dormancy of the rhizome in myoga is an endogenous dormancy. The mechanisms that are involved in regulating this dormancy process are as yet unknown. A more detailed understanding of the interactions between the length of the dormancy period and the effects of chilling treatments on the commencement of pseudostem growth is required to manipulate this dormancy period and promote the onset of pseudostem growth in myoga. This report describes the effect of preplant chilling of myoga rhizomes on the dormancy of rhizomes, specifically as this relates to pseudostem emergence and growth rate.

2. Methods

2.1. Plant material and growth conditions

Dormant rhizomes were obtained from myoga plants maintained in a glasshouse, during autumn immediately after senescence. Rhizomes were cut into short lengths of known weights and soaked in a preventative fungicide mixture (Ronalin \textit{(vinclozolin)}, Baviston \textit{(carbendazim)}, Benlate \textit{(benomyl)} and Previcur \textit{(propamocarb)}). Rhizomes were planted into trays containing potting soil. The potting soil consisted of peat, sand and pine bark (1 : 2 : 7) which was supplemented with slow release fertiliser (nine month osmocote 300 g/50 l (18% N, 2.6% P, 10% K, 4.7% S, 0.8% Ca)), dolomite (300 g/50 l), iron sulphate (25 g/50 l) and trace elements (micromax 20 g/50 l (15% S, 12% Fe, 2.5% Mn, 1.0% Zn, 0.5% Cu, 0.1% B, 0.05% Mo)). The pots were watered daily.

2.2. Treatments

Rhizome dormancy and pseudostem emergence were investigated in two separate trials undertaken in 1995 and 1996. The first trial examined the effect of a 3 week preplant rhizome chilling treatment on pseudostem emergence and growth. The second trial extended the chilling treatments to include varying lengths of chilling and the data collected were extended to include pseudostem emergence, number of pseudostems per rhizome, as well as timing, weight and number of flower buds.
2.3. Experiment 1

Rhizome segments weighing 40 ± 5 g were collected from plants immediately after senescence and were stored in moistened pine bark at 20°C prior to planting. At 3 week intervals, commencing immediately following rhizome collection and continuing over a 12 week period, rhizomes were planted 2 cm deep in potting soil. Prior to planting, rhizomes were subjected to one of two chilling treatments. The treatments were no chilling (rhizomes held at 20°C) or 3 weeks chilling at 4°C. 10 rhizomes from each chilling treatment were planted at each of the planting dates.

The number of days from the date of planting until the first pseudostem emerged from the potting medium was recorded. Pseudostem growth rate was recorded as the interval in days from emergence to pseudostems reaching 30 cm in height.

2.4. Experiment 2

Rhizome segments weighing 100 ± 10 g were collected from plants immediately after senescence and were stored in moistened pine bark at 12°C before planting. Six rhizomes from each chilling treatment were planted 8 weeks after collection after having received chilling treatments. The chilling treatments were 0, 1, 2, 4 and 8 weeks chilling at 4°C. Rhizomes were planted in 20 l pots at a depth of 10 cm and were arranged in a randomised design in a glasshouse at 20 ± 5°C.

Plants were examined at regular intervals. The date of pseudostem emergence and the number of pseudostems produced per plant were recorded. Flower buds were harvested as they emerged from the potting media. The number and fresh weight of flower buds produced by each plant was recorded.

3. Results

3.1. Experiment 1

Dormant myoga rhizomes collected from recently senesced plants and held at 20°C in a growth chamber produced pseudostems (Fig. 1). This indicates that there is no absolute requirement for chilling to stimulate pseudostem growth from rhizomes. However, at least during the first 3 weeks after collecting rhizomes from recently senesced plants, chilling significantly decreased the time to pseudostem emergence. From 6 weeks onwards, pseudostems from the unchilled rhizomes emerged at much the same time as from the chilled rhizomes.

A 3-week chilling treatment at 4°C resulted in a mean (±standard deviation) time to shoot emergence of 26.7 ± 1.8 days after planting at each planting date.
Variability in emergence time, expressed as the coefficient of variation of the mean, decreased from 30.95% at the first planting date to 24.17%, 14.35%, 10.12% at each of the later planting dates respectively.

Time to emergence of non-chilled rhizomes decreased from 72 days at the first planting date to 33 days at the third planting date. There was no significant difference in time to emergence between chilled rhizomes and non-chilled rhizomes over the final three planting dates. These results suggest that the length of the dormant period in non-chilled myoga is approximately 6 weeks with a further 4 weeks required after planting for pseudostem emergence. Development of pseudostems after emergence was not affected by chilling with all treatments recording similar growth rates following emergence. From emergence to 30 cm height took a mean of 18.4 ± 0.28 days.

3.2. Experiment 2

The duration of chilling received by rhizomes before planting had a significant influence on the time from planting to pseudostem emergence (Fig. 2a). Rhizomes chilled at 4°C for 8 weeks were found to emerge significantly earlier
Fig. 2. (a) Days from planting to pseudostem emergence. Rhizomes were chilled at 4°C for 0, 1, 2, 4 or 8 weeks prior to planting. Bars show SE (n = 6). (b) Cumulative number of pseudostems emerged, (c) cumulative number of flower buds produced, and (d) cumulative fresh weight (g) of flower buds produced after chilling the rhizomes for 0 (○), 1 (●), 2 (△), 4 (▲) or 8 (□) weeks at 4°C. Each point is the mean of six replicates. Bars show lsd (p = 0.05).
than rhizomes chilled for 0, 1, 2 or 4 weeks. The results show a trend towards reduced time to emergence and reduced variability in emergence with increasing length of chilling at 4°C. Pseudostem growth was characterised by two distinct flushes of emergence, with the initial development of two to three pseudostems following planting and the further development of four to seven pseudostems over a longer period of time between 50 and 100 days after planting. Rhizomes chilled for 8 weeks produced pseudostems earlier than the other treatments throughout the experiment but the rate of pseudostem production and the total number of pseudostems produced did not vary between treatments (Fig. 2b). The rate of pseudostem production was recorded as the number of days from the commencement of pseudostem emergence to 50% emergence. The two phases of pseudostem emergence were analysed separately and no significant differences ($p < 0.05$) were found between chilling treatments in either of the two phases which resulted in a mean time (±standard deviation) to reach 50% emergence of 3.8 ± 0.80 and 10.9 ± 5.72 days, respectively. Differences in the cumulative number of pseudostems developing during the two phases of pseudostem emergence are shown in Fig. 2b. Since there are no differences in rate of pseudostem production the differences in cumulative number of pseudostems are consistent with the earlier commencement of pseudostem development of rhizomes chilled for 8 weeks. Pseudostem emergence had ceased by 100 days after planting. The production of flower buds occurred between 100 days after planting and plant senescence which occured approximately 230 days after planting.

The plants given 8 weeks chilling commenced flower production before the other treatments, however, there was no significant difference in mean number of flowers produced per plant between duration of chilling treatments (Fig. 2c). The weight of flowers per plant produced by plants given 8 weeks chilling was significantly lower than that produced by plants given 0, 1 or 4 weeks chilling (Fig. 2d). As total flower number did not differ significantly between treatments, flowers produced after 8 weeks chilling were lighter than those produced by plants receiving 0, 1 or 4 weeks chilling. Mean flower weight produced by plants chilled for 8 weeks was 8.8 g, while the mean flower weight of plants chilled for 0, 1, 2, 4 weeks was 12.5, 13.0, 13.2, and 14.8 g, respectively.

4. Discussion

Rhizome dormancy in myoga was shown in this study to be of approximately 6 weeks duration, and the loss of dormancy does not require a low temperature. In this regard, myoga responds in a similar way to many more widely studied storage organs such as the tuber forming crops potatoes and yams (Suttle, 1996), the bulb crop onions (Miedema, 1994a), and the rhizome crop ginger (Hasanah A.J. Gracie et al. / Scientia Horticulturae 84 (2000) 27–36
and Satyastuti, 1989). In all these crops and myoga, dormancy of the storage organs can be terminated prematurely by chilling. The results from this study suggest that the prolonged dormancy observed in plants held overwinter in the field, arises from an exodormancy mechanism, most likely being low temperature.

These findings differ significantly from Maeda (1994) who demonstrated that non-chilled rhizomes failed to produce pseudostems for an unspecified time (but >90 days) after planting, indicating a much longer dormant period than noted in this study. This difference may arise from either a genetic or physiological difference between the materials used in the two studies. Genetic variability in the pattern of growth of myoga was described by Maeda (1994) in an examination of early and late flowering varieties, and similar variability in dormancy periods may explain the inconsistency between the two findings.

Variability in the depth and duration of dormancy due to the physiological state of buds has recently been reviewed by Crabbe and Barnola (1996). The dormancy patterns of buds of a number of woody species have been shown to relate to position of the bud on the plant, while the release of buds from dormancy may be related to the chain of correlative events leading up to dormancy. Changes in the physiological state of dormant buds of myoga during the course of dormancy or differences in the conditions leading up to dormancy, could therefore contribute to variation in observed responses of dormant rhizome sections to chilling treatments.

Increased uniformity in shoot emergence with later plantings of both chilled and non-chilled rhizomes indicates variability in the physiological state of the buds on rhizomes when rhizomes were first divided. Storage periods exceeding the dormancy requirement of rhizomes resulted in rapid sprouting when rhizomes were planted. Longer periods of chilling also resulted in increased uniformity in shoot emergence and decreased time to shoot emergence, suggesting that rhizomes may reach the physiological state required for shoot emergence at the completion of the dormancy period or following a period of chilling prior to the end of the dormancy period.

A number of important physiological changes associated with the breaking of dormancy in plant storage organs have been reported in the literature. In potato tubers release from dormancy has been correlated with changes in soluble sugar concentrations arising from an alteration in the balance of sugar synthesis and remobilisation (Hill et al., 1996), changes in the pattern of soluble proteins expressed in the tuber (Désiré et al., 1995), altered membrane structures and function (O’Donoghue et al., 1995) and changes in plant hormone concentrations (Hemberg, 1985). Similar changes preceding shoot emergence are reported in bulb crops such as onions (Miedema, 1994b), and tulips (Lambrechts et al., 1994). It seems probable that similar changes may be occurring in myoga at the completion of the dormancy period or following chilling treatments.
The growth rate of pseudostems after emergence was shown to be independent of the time of emergence or chilling treatment imposed. The duration of chilling did, however, appear to influence the flowering response of the plant. The total fresh weight of flowers produced by rhizomes chilled for 8 weeks at 4°C prior to planting was significantly lower than in plants chilled for shorter durations, while the pseudostem growth response was similar irrespective of chilling treatment. Thus flower bud development must be influenced by the physiological state of the rhizome at planting.

Chilling of rhizomes prior to planting may be used as an effective treatment to overcome dormancy and promote uniformity in pseudostem emergence. The length of the dormant period in myoga rhizomes is likely to vary according to the prior growth condition of the mother plant, the position of the rhizome within the mother plant, and the variety of myoga being cultivated. Effective chilling treatments are therefore likely to be dependent on the duration of dormancy. Under Tasmanian glasshouse conditions, a chilling treatment of 2–4 weeks at 4°C is effective in overcoming the short dormancy period.

Acknowledgements

The authors thank Mr Peter Shelley and Mr Richard Warner of ‘Agrimark’ and Rural Industries Research and Development Corporation for supporting this project.

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