Within Umbel Flowering Pattern for Garlic Chives (*Allium tuberosum* Rottler) and Seed Development for Garlic Chives, Onion Chives (*A. schoenoprasum* Schnittlauch) and Multi-tillered Chive Selections (*A.* spp.).

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ABSTRACT

Chives (*Allium* spp.) are reputed to have medicinal properties and have potential for inclusion in pasture mixes for low input farming. However, there appear to be no data in the literature on the seed development of chive species. Three selections of *Allium* species (garlic chives, onion chives and a multi-tillered selection) were planted in a 20 x 15 cm grid at Lincoln AgResearch farm in September 1992. Seed development was studied in the second flowering year (November 1993 to May 1994); thousand seed weight, seed moisture and germination were recorded. Flowering pattern was recorded for the garlic chives and individual seedling weight was measured for the onion and multi-tillered chives. Garlic chives flowered 3.5 months later than the other chives, and maximum seed maturity was achieved 65 days after flowering *cf.* 37 and 42 days for the onion and multi-tillered chives respectively. At this stage, seed moisture content was 50, 31 and 25% for the garlic, onion and multi-tillered chives, respectively, and seedling weight for the onion and multi-tillered chives was near maximum.

Additional index words: Allium schoenoprasum, Allium tuberosum, germination, seed moisture, seed vigour.

INTRODUCTION

Interest in low input farming has prompted research into species which are believed to have properties different to those of normal pasture species, e.g., the ability to concentrate certain minerals, deep-rooting ability (Kiley-Worthington, 1981; Foster, 1988) or the prescence of tannins (Fraser and Rowarth, 1996). Further interest has been generated in species which are reputed to have medicinal or anthelmintic properties (Knight, Moss, Fraser, Rowarth and Burton, 1996; Fraser, Rowarth and Knight, 1997) and those which might enhance meat quality (Fraser, Scott and Rowarth, 1996). Enhanced animal performance with minimal chemical input is desired. This is considered extremely desirable in New Zealand, as export markets require preservation of the 'clean, green image'.

The *Allium* family, particularly garlic (*Allium sativum* L.), has been used traditionally in a medicinal role, and is reputed to be effective against intestinal worms when used as a drench (S. Stephens, Rural Press, pers. comm., 1993). Garlic is propagated by cloves (Loewenfeld and Back, 1976), which renders inclusion in a pasture seed mixture impracticable. However, garlic chives (*A. tuberosum* Rottler) and onion chives (*A. schoenoprasum* Schnittlauch) do produce seed and also have medicinal properties.

Onion chives are a member of the onion family. They have round, hollow leaves and close-packed purple umbels. As culinary herbs they are popular for their taste and colour. They are also reputed to stimulate the appetite and promote digestive processes (Loewenfeld and Back, 1976; Jakobey, Habegger and Fritz, 1988). They are a native of Europe, including Britain, and may also be found growing wild in Canada and northern America (Loewenfeld and Back, 1976). Chives can be grown readily from seed or by plant division.

Garlic is more pungent than chives and is reputed to have more intense properties, ranging from protection against colds and influenza to vampires (Hawkins, 1986). Garlic is believed to have originated in Central Asia, but has been cultivated for so long in so many countries that there are doubts about the existence of any true 'wild-type' garlic (Loewenfeld and Back, 1976).

There are several species of 'chive', varying in appearance, taste and properties between the onion chive and garlic. The garlic, or Chinese, chive has flat, garlic-flavoured leaves and forms tall, white flowered, spreading umbels. Because of difficulties in obtaining seed from this species, *in-vitro* propagation has been investigated (Shuto, Abe and Sasahara, 1993). However, this is a relatively expensive technique for a plant whose medicinal value does not compare with garlic.

Botanical descriptions of flowers and seed are available for *Allium* species (Loewenfeld and Back, 1976): the fruit capsule contains 3-4 three-sided black seeds located in compartments found in the flowers of the umbel. Each floret has three compartments and two seeds can form per compartment.

This paper reports on the seed development of three contrasting chive selections from *A. tuberosum, A. schoenoprasum*, and a multi-tillered selection.

MATERIALS AND METHODS

Three selections of *Allium* species (garlic chives, onion chives and multi-tillered chives) were provided as seedlings by Dr W. Rumball, AgResearch, Palmerston North, New Zealand. They were planted in a 20 x 15 cm grid at Lincoln AgResearch farm, Canterbury, New Zealand, on a Udic Ustochrept, in September 1992; the current research began in the second flowering season. During both seasons the plants (which were not cut) were hand-weeded and irrigated when necessary. Climate data were collected at the Broadfields Meteorological Station, 3 km from the experimental site.

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Ten umbels were tagged on 25 February 1994 at the beginning of umbel sheath split. At 3-4 day intervals after tagging, the following were recorded: days to flower exposure from sheath split, die back of flowers, optimum number of flowers to reach maturity, capsule split pattern; days to complete pollination (when all flowers had just wilted), days to seed capsules splitting and shedding of seeds. Results were related to days after sheath split (DAS).

For seed development studies, outer flowers of the umbel were tagged in garlic chives, and whole heads were tagged in onion and multi-tillered chives. One hundred umbels or heads were tagged at peak flowering (28 February 1994 for garlic chives and 17 November 1993 for onion and multi-tillered chives; identified by monitoring flower head numbers) when first outer flowers emerged, exposing the stamens and stigma. Five umbels or heads were collected at 3-4 day intervals, from 15 days after tagging (garlic chives) or 7 days after tagging (onion and multi-tillered chives), until seed shattering. Results were related to days after flowering (DAF). Number of seeds per capsule and fresh weight of dissected seed were recorded for garlic chives. For onion and multi-tillered chives data recorded included total number of flowers per tagged head, total number of seeds dissected from five central flowers of a tagged head and total weight of the seed.

Dissected seeds of multi-tillered chives, onion chives and garlic chives were oven-dried at 25 °C to a stable weight. Dry weights obtained were used to calculate seed moisture percentage and thousand seed weight (TSW). Within four weeks of harvest, seeds were pre-chilled at 5 °C for 7 days prior to germination on top of filter paper at alternating day-night temperatures of 20 and 15 °C. Germinating seeds were counted at 6 days and again at 14 days (ISTA, 1993). Seedling weight, as a measure of seed vigour (Hampton and TeKrony, 1995), was measured at the final germination count for onion and multi-tillered chives.

RESULTS

Temperature and humidity were similar to the previous five year average in most months (Table 1). Exceptions were that December was 2 °C cooler, February was 2 °C warmer and March and April were less humid than usual. Solar radiation was lower than usual except in February and April. April and May were drier than usual, but November, December, January and March were wetter.

Garlic chives

Garlic chives averaged 53 florets per umbel, 28% of which were in an outer ring. The time of exposure of flowers from the bud sheath, pollination of flowers, and time of capsule split, differed between the outer and inner flowers of the umbel. Outer flowers emerged gradually from the bud sheath at the rate of 0.6 flowers per day, reaching a maximum of 15 outer flowers per umbel by 28 DAS (Fig. 1). The number of flowers emerged remained constant for another 5 days and then decreased because of flower death at the rate of 0.3 per day, stabilizing at a constant number of 11 flowers during 45 to 60 DAS. Capsules started splitting and shedding seeds after 60 DAS, at the rate of 0.3 capsules per day. All the flowers had completed pollination by 31 DAS. The inner flowers were more numerous, but flowered in a similar pattern to that of the outer flowers (Fig. 2). Flowers were exposed from the bud sheath at the rate of 1.1 per day, reaching a maximum of 37 by 33 DAS. All flowers had completed pollination by 39 DAS and total flowers decreased thereafter at the rate of 1.4 per day, maintaining a constant number of 15.3 from 48 to 56 DAS. Seed capsules started splitting and shedding seeds after 56 DAS, at the rate of 0.4 capsules per day.

Seed moisture content decreased significantly ($P<0.05$) from 83% at 15 DAF to 38% at 72 DAF, a rate of approximately 0.52% per day (Fig. 3). At the same time, TSW increased significantly ($P<0.05$) to 4.5 g, although increases after 65 days were not significant. In contrast, seeds did not begin to germinate until 40 DAF, increasing significantly ($P<0.05$) to a maximum of 58% at 65 DAF, and decreasing significantly from 65-72 DAS.

Onion chives

Onion chives averaged 59 florets per head, all of which were held compactly.

Seed moisture in onion chives decreased significantly ($P<0.05$) from 80% at 7 DAF to 30% at 42 DAF, a rate of 1.9% per day (Fig. 4). Thousand seed weight (TSW) increased significantly ($P<0.05$) from 0.28 to 1.0 grams at the rate of 0.03 g per day from 7 DAF until 34 DAF (Fig 4). Germination of seeds increased significantly ($P<0.05$) from 23 DAF at the rate of 5% per day, reaching a maximum germination of 77% at 37 DAF (Fig. 4).

Individual seedling weight increased sigmoidally with time; significant increases in weight occurred between 23 and 30 days (Fig. 5).

Table 1. Meteorological data for the period of the trial. Figures in brackets are the average for the previous five years.

Month	Mean air temperature (°C)	Soil temperature (°C @ 10 cm)	Mean humidity (%)	Total solar radiation (Mjm^{-2})	Thermal time[1]	Rainfall (mm)
November 1993	11.2 (13.4)	13.3 (12.9)	76.1 (74.2)	583 (619)[2]	328.3	75.6 (45.0)
December	13.5 (15.4)	14.6 (14.9)	70.7 (70.5)	620 (720)	404.8	99.8 (68.3)
January 1994	17.3 (16.9)	17.2 (16.9)	71.5 (74.6)	696 (730)[2]	521.5	50.3 (40.0)
February	16.7 (16.1)	17.9 (16.0)	79.9 (75.9)	571 (547)[2]	459.4	37.8 (38.9)
March	13.3 (14.8)	14.4 (14.1)	59.9 (79.9)	396 (467)	412.0	81.0 (34.2)
April	12.3 (11.5)	10.4 (9.8)	71.3 (80.3)	310 (298)[3]	361.2	17.5 (57.2)
May	8.8 (9.0)	8.4 (6.7)	81.1 (86.7)	177 (196)	276.5	47.2 (61.7)

[1] *Growing degree days; 0 °C base temperature*
[2] *Based on average of three preceding years.*
[3] *Based on average of two preceding years.*

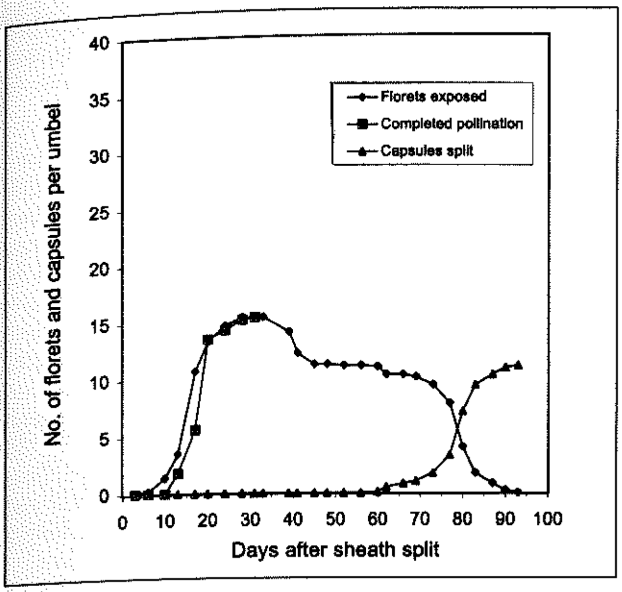

Figure 1. Flowering pattern for the outer florets of the garlic chive umbel.

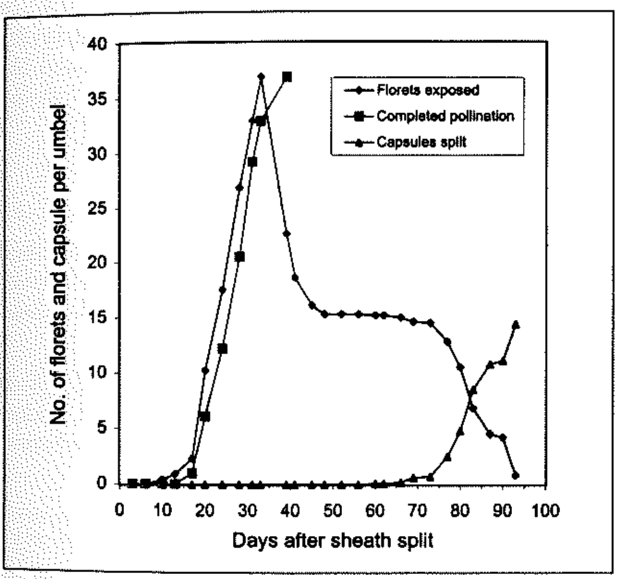

Figure 2. Flowering pattern for the inner florets of the garlic chive umbel.

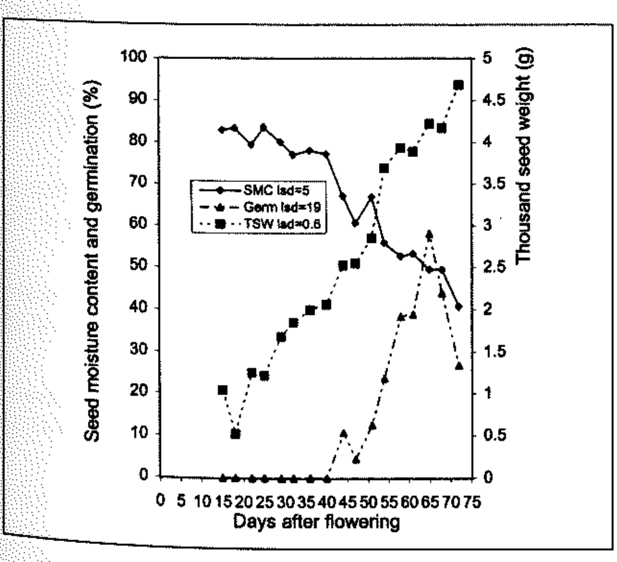

Figure 3. Changes in seed moisture content, seed weight and germination after flowering in garlic chives.

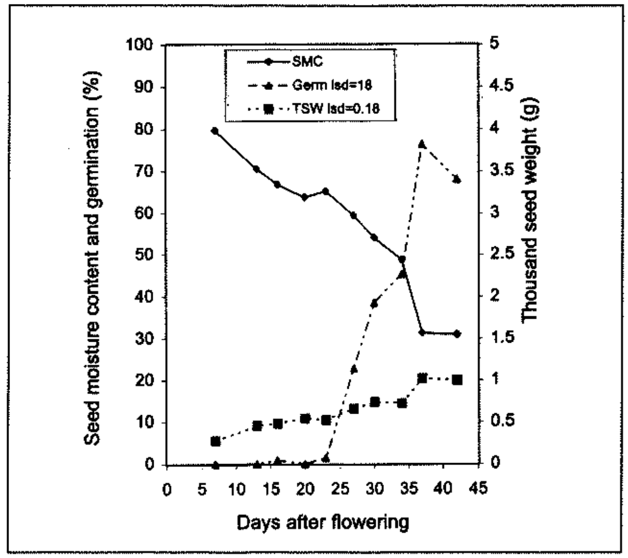

Figure 4. Changes in seed moisture content, seed weight and germination after flowering in onion chives.

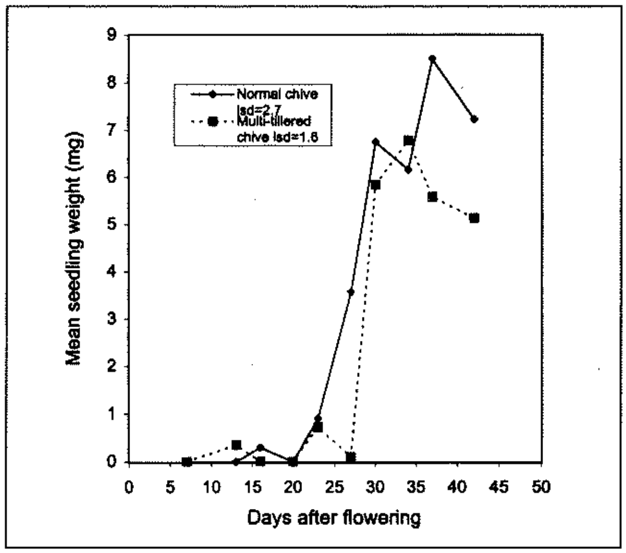

Figure 5. Effect of time after flowering on seedling weight (mg per seedling) for onion and multi-tillered chives.

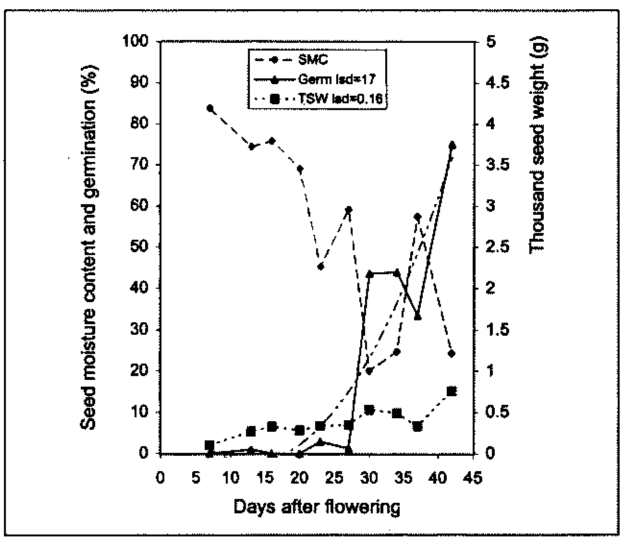

Figure 6. Changes in seed moisture content, seed weight and germination after flowering in multi-tillered chives.

Multi-tillered chives

The multi-tillered chive selection averaged 35 florets per head, all of which were held compactly.

In multi-tillered chives, seed moisture decreased significantly ($P<0.05$) from 84% at 7 DAF to approximately 20% at 42 DAF, a rate of 2.3% per day (Fig. 6). Thousand seed weight (TSW) increased significantly ($P<0.05$) from 0.10 g at 7 DAF to 0.8 g 42 DAF at a rate of 0.03 g/day (Fig. 6). Germination of seeds increased significantly ($P<0.05$) from 27 DAF at the rate of 4% per day, reaching a maximum germination of 75% at 42 DAF (Fig. 6).

Individual seedling weight increased sigmoidally with time; a significant increase occurred between 27 and 30 DAF (Fig. 5).

DISCUSSION

Garlic chives flowered three and a half months later than the onion and multi-tillered chives and seed development was almost twice as slow (65 days *cf.* 37-42 days). Although radiation intensity is reduced and daylight length is shorter in autumn than late summer, growing degree days (GDD; mean thermal time; base 0 °C) were higher for the total period of the garlic chive seed development (803 *cf.* 444-510 °C). This indicates that the difference in seed development was associated with species rather than climate. As a consequence of the later flowering and slow seed development of the garlic chives, seed maturity was not achieved until May, which has implications for commercial harvest.

Seed is physiologically mature when seed dry weight reaches a plateau (Hyde, 1950), and can be harvested when it is sufficiently dry to process through machinery (Delouche, 1980). In all chive plants, approach of seed maturity was indicated by seed cases turning from green to black.

In garlic chives, TSW did not plateau before shattering occurred; germination was maximum at 65 DAF, at which stage seed moisture was about 48%. Seed germination reduced with further seed drying (on the plant), indicating the development of embryo dormancy. Maximum germination was only 60%, which may reflect the lengthy development period; decreases in seed quality have been observed in late flowering in such species as lotus (Bologna, Rowarth and Fraser, 1996). Method of harvesting (e.g., desiccant, swathing) should be investigated to ensure maximum seed yields can be achieved.

In onion chives, TSW, germination and seedling weight were maximum at 37 DAF, when seed moisture was down to 30%. Although seed would require further drying for safe storage if harvested at this moisture content, leaving the seed would result in losses due to shattering.

In multi-tillered chives, TSW and germination were maximum at 42 DAF, when seed moisture was down to 25%. Seed moisture in multi-tillered chives varied markedly with rainfall, possibly due to the water holding capacity of the relatively large number of dead flowers on the heads. Seedling weight in multi-tillered chives did not change significantly after 30 DAF.

For all chives, harvesting the crop before most seeds reached physiological maturity resulted in lighter seeds, with reduced germination, because of immaturity of most of the seed. Delaying the harvest until after physiological maturity had no detrimental effect on seed weight and germination, but resulted in a sharp reduction in seed yield because of progressive loss of seed from shattering.

As considerable year to year variation in GDD can occur, 'days after peak flowering' (or anthesis) is not a reliable indicator of time to harvest, even though it has been used extensively in the literature (e.g., Hare and Lucas, 1984; Hare, 1986; Young, 1993). Seed moisture content is likely to be the best guide for timing harvest, in the absence of more information on GDD. Garlic chives could be harvested at a SMC of 50% whereas onion and multi-tillered chives can be harvested at 31% and 25% SMC, respectively. However, there is potential for damaging seed when harvesting at high seed moisture (Castillo, Hampton and Coolbear, 1992); further research is necessary to investigate appropriate harvesting methods and timing to maximise seed yield and vigour in chives, and to confirm whether these data from a single season are, in fact, repeatable.

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