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Effect of weight of potato minitubers on sprout growth, emergence and plant characteristics at emergence

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Summary

The behaviour of minitubers in five weight classes, having mid-point values between 0.19 and 3.00 g, was studied during sprouting and emergence under controlled conditions. Lighter tubers took longer to produce sprouts of 2 mm, and their sprouts grew more slowly between 2 and 4 mm and 4 and 6 mm. As sprouts lengthened their rate of growth increased. The influence of tuber weight was less for heavier tubers and also decreased as the sprouts grew longer. When tubers with sprouts of the same length were planted in pots, sprouts from lighter tubers took longer to emerge. Emergence was later and differences between weight classes were larger when tubers were planted deeper (6 or 9 cm) or when they had shorter sprouts at planting (2 or 4 mm). At emergence, plants from lighter tubers had thinner stems and lower stem and root weights, but higher stem weights proportional to tuber weights and higher shoot:root ratios.

Introduction

Potato minitubers can be used for seed tuber production under field conditions. However, early attempts to grow a crop from minitubers were often unsuccessful because of reduced or delayed emergence, probably mainly due to an insufficiently long sprouting period, associated with the small tuber size. Insufficient sprouting could have resulted from the long dormant period of minitubers, which is longer with lighter tubers (Emilsson, 1949; Van Ittersum & Struik, 1992; Lommen, 1993), and therefore makes a relatively short period available for sprouting. Even after the same period for sprout growth, sprouts from tubers with lower weights could be smaller at planting, because the rate of sprout elongation during the sprouting period is positively correlated with the amount of substrate available for growth (Morris, 1966). If sprouts are smaller at planting, this will result in a later emergence (Sadler, 1961). In addition, other problems resulting from biotic or abiotic stresses may occur between planting and emergence.

This paper describes the results of three related experiments, carried out to obtain information on the effects of the weight of minitubers on sprout elongation during the sprouting period and on growth between planting and emergence.

Materials and methods

Three experiments were carried out in growth chambers, using minitubers from cvs Ostara, Bintje and Elkana in five weight classes: I 0.13–0.24 g; II 0.25–0.49 g; III 0.50–0.99 g; IV 1.00–1.99 g; V 2.00–3.99 g. The range of weights doubled with each consecutive class, and results are presented by plotting the middle value of each class on a log scale.

Expt 1. Minitubers were cured after harvest for 14 days and stored at 2 °C in darkness until 105 days after harvest. They were sprouted in darkness (to promote sprout elongation) at 18 °C and 80% RH. Tubers were placed with the apical eye upwards in a thin layer of dry sand to keep them in an upright position. The length of the sprouts was measured every 2 days until they were 8 mm long. Measurements took place under low intensity green light. Ten tubers, each producing one sprout, were used for each combination of cultivar and fresh weight class.

Expts 2 and 3. Time to emergence and plant growth until emergence were studied in two partly overlapping experiments. Individual tubers producing one (apical) sprout were sprouted as in Expt 1 until the sprout was 2, 4 or 8 mm long. The tubers were then stored at 4 °C to prevent further increase in length until 205 days after harvest when all tubers had sprouts of the desired length. Thereafter, sprouted tubers were exposed to light for 11 days and planted in individual 12.5 cm high pots containing 350 ml of coarse quartz sand supplemented with a complete nutrient solution.

Treatments applied in Expt 2 were all combinations of:
(a) Planting depth: 3, 6 and 9 cm;
(b) Tuber fresh weight class: I to V;
(c) Cultivar: Ostara, Bintje and Elkana.
All tubers had sprouts of 2 mm at planting.

Treatments applied in Expt 3 were all combinations of:
(a) Sprout length at planting: 2, 4 and 8 mm;
(b) Tuber fresh weight class: I to V;
(c) Cultivar: Ostara, Bintje and Elkana.
In Expt 3, all tubers were planted 6 cm deep.

In both experiments, all treatments were replicated ten times, using a completely randomized design. The temperature after planting was 18 °C during the day (16 h) and 12 °C during the night (8 h). Emergence was checked daily and plants were analysed the day they emerged for fresh weights of root, stem (= shoot) and mother tuber, as well as the length of the stem and its diameter in the middle region.

Results

As the main purpose of this paper was to study the effects of the weight of the mother tuber, all results are presented as average values for the three cultivars. Interactions with cultivar sometimes occurred ($P<0.05$) but they were always less significant than the effects presented in the table and figures, and merely reflect differences in the clearness of the effects.

Table 1. Expt 1. Influence of the fresh weight class of minitubers on the time required for the apical sprout to grow to 2 mm, from 2 to 4 mm, from 4 to 6 mm and from 6 to 8 mm. Mean of three cultivars.

	Mid-point of minituber weight class (mg)					LSD 5%
	187	375	750	1500	3000	
Days from harvest to produce a sprout 2 mm long	153.9	146.7	142.1	136.7	134.7	1.7
Additional days taken to grow from: 2–4 mm	16.6	14.1	10.9	8.2	7.5	1.8
4–6 mm	7.1	5.4	3.9	5.3	4.9	1.6
6–8 mm	3.5	3.1	2.6	2.9	3.3	0.9

Increase in sprout length during sprouting (Expt 1). Heavy minitubers produced a 2 mm apical sprout sooner than light ones (Table 1). Sprouts from heavy minitubers also grew more rapidly between 2 and 4 mm and between 4 and 6 mm than those from lighter tubers. However, differences between weight classes were smaller in the upper ranges of tuber weight and when sprouts became larger (Table 1). The time to grow from 6 to 8 mm did not differ significantly between the weight classes. In all classes, the increase in length was faster as the sprouts became longer ($P<0.001$).

Emergence and pre-emergence growth (Expts 2 and 3). When tubers, with 2 mm sprouts, were planted 3, 6 or 9 cm deep (Expt 2), the sprouts from on average 5.7% of the tubers from the lowest weight class did not emerge within 30 days. Sprouts from all other tubers emerged. Non-emerging plants were excluded from further analysis and so were plants that had produced more than one main stem (6.3%) or a branched main stem before emergence (5.2%; they were mainly in the two lowest weight classes). Of the remaining tubers, the mean time to emergence decreased for heavier tubers and when minitubers were planted less deep (Fig. 1). Differences in time to emergence between weight classes were much larger with deeper planting (Fig. 1).

When tubers with sprouts of 2, 4 and 8 mm were planted 6 cm deep (Expt 3), sprouts from on average 4.2% of the lightest tubers did not emerge. All heavier tubers produced an emerging sprout. Again, the non-emerging plants and the plants that had produced more than one main stem (4.5%) or a branched main stem (4.3%) were excluded from further analysis. The mean time to emergence again decreased with increasing minituber weight (Fig. 2). The time to emergence was shorter when tubers had longer sprouts at planting (Fig. 2). In addition, differences in time to emergence between low and high weight classes were larger when minitubers had small (2 or 4 mm) compared to larger (8 mm) sprouts at planting (Fig. 2).

The results of Expt 3, averaged over the three initial sprout lengths, showed that stems from lighter tubers were thinner than those from heavier tubers (Fig. 3) and that they grew further before emerging (Fig. 3). In addition to possible slight differences in planting depth (probably of no more than 6–7 mm) due to different

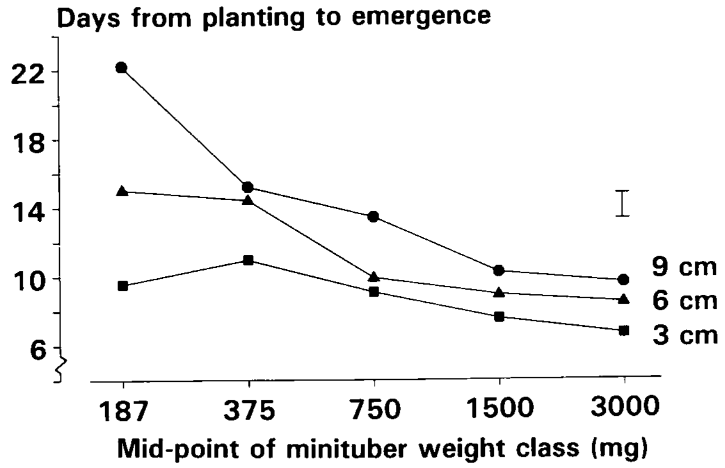

Fig. 1. Expt 2. Influence of the minituber weight class on the time to sprout emergence from three depths of planting in pots. Average values of three cultivars; sprout length at planting 2 mm. Bar: LSD 5%.

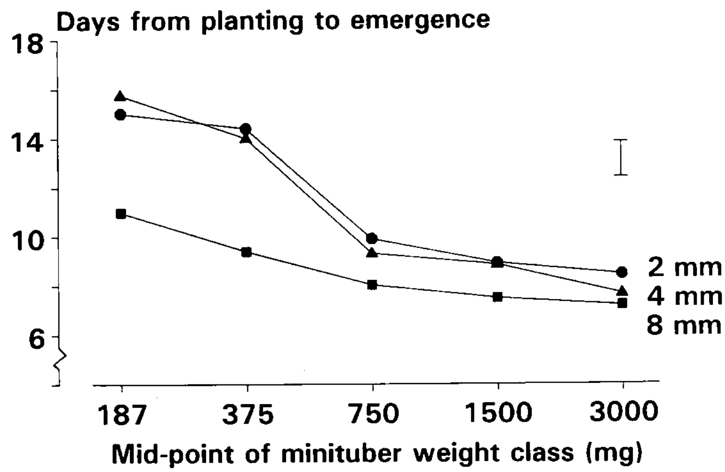

Fig. 2. Expt 3. Influence of the minituber weight class on the time to sprout emergence for three sprout lengths at planting. Average values of three cultivars; planting depth 6 cm. Bar: LSD 5%.

tuber diameters, the greater length was because most of these stems did not grow straight to the surface.

At emergence, both stem and root fresh weights increased with increasing weight of the minitubers (Fig. 4), but the shoot:root ratio was much higher in plants from lighter tubers (Fig. 4). This higher shoot:root ratio was mainly due to a much higher stem weight compared to the weight of the mother tuber at emergence in plants from

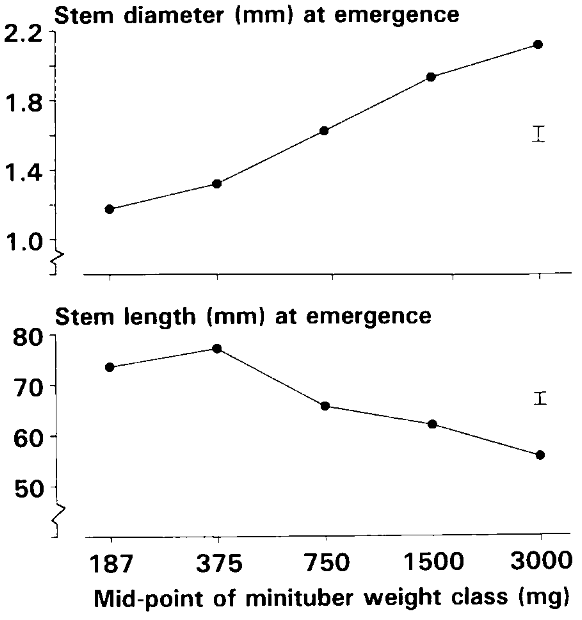

Fig. 3. Expt 3. Influence of the minituber weight class on stem diameter and stem length at emergence. Average values of three cultivars and three sprout lengths at planting; planting depth 6 cm. Bar: LSD 5%.

smaller tubers (Fig. 5). The ratio between root fresh weight and fresh weight of the mother tuber differed only slightly between tubers of different weights (Fig. 5).

Discussion

Increase in sprout length during sprouting. The dormant period (defined here as the period from harvest until the apical sprout of a tuber is 2 mm long) was longer for lighter minitubers (Table 1). This is in accordance with other studies on minitubers (Lommen, 1993) and conventional tubers (Emilsson, 1949; Van Ittersum & Struik, 1992) although slightly different characteristics were used to define the dormant period. A slower rate of initial sprout growth up to 2 mm almost certainly contributed to this effect, because sprouts of tubers from lower weight classes were still growing more slowly between 2 and 4 mm and 4 and 6 mm (Table 1). No data are available on the onset of sprout growth. The results confirm the observation of Krijthe (1962), that initial sprout growth up to 3 mm was slower in smaller tubers. Van Ittersum et al. (1992) observed no consistent effects of tuber weight on initial sprout elongation. This was probably because they used heavier tubers (25 g and 80 g), for differences in sprout elongation rate between fresh weight classes diminished when tuber weights became higher (Table 1).

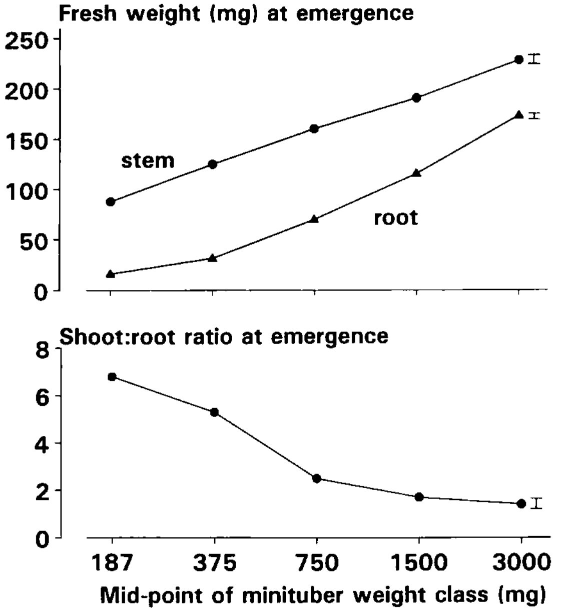

Fig. 4. Expt 3. Influence of the minituber weight class on stem and root weights and shoot:root ratio (fresh weight basis) at emergence. Average values of three cultivars and three sprout lengths at planting; planting depth 6 cm. Bar: LSD 5%.

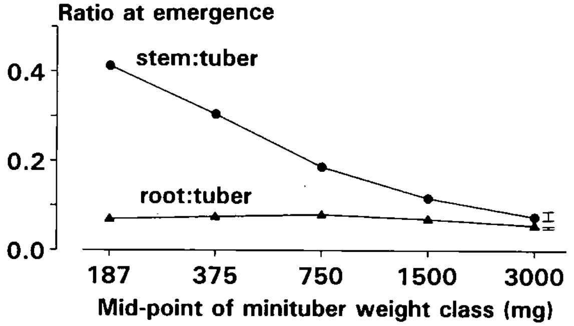

Fig. 5. Expt 3. Influence of the minituber weight class on the ratios between fresh weights of stem and mother tuber, and between root and mother tuber, at emergence. Average values of three cultivars and three sprout lengths at planting; planting depth 6 cm. Bar: LSD 5%.

Emergence and pre-emergence growth. Table 1 suggests that if all tubers are sprouted for the same period, those from the lowest weight classes will have the smallest sprouts. Consequently, differences in time to emergence between tuber classes will be extremely large because (a) stems from lighter tubers emerge later even if the sprouts are the same length at planting (Figs 3, 4); and (b) stems from tubers with smaller sprouts emerge later (Fig. 2; Sadler, 1961; Headford, 1962; Firman et al., 1992). By planting minitubers with longer sprouts (up to 8 mm, the maximum studied), both the time to emergence can be shortened and differences between tubers with different weights can be reduced. However, this will require a much longer sprouting period for tubers with lower weights, and consequently an adjustment of the sprouting period depending on the tuber weight. In practice, this could probably be achieved by narrow grading of the tubers after curing, and sprouting batches separately for the appropriate period.

The later emergence of stems from smaller tubers was mainly due to a slower increase in length after planting (Figs 3, 4). In addition, however, stems from lighter tubers grew farther before they emerged (Fig. 3), probably partly because their growth had not been completely negatively geotropic. Some stems, however, especially the thinner stems from light tubers, seemed to have been impeded by the soil, as indicated by the fact that they were curved or coiled. The coarse sand used may have enhanced this effect.

Time to emergence is probably negatively related to the rate at which reserves from the mother tuber become available for stem growth (cf. Moorby, 1967) and positively to the total weight of the stem produced at emergence. Sprouts emerge earlier if they were larger when the tubers were planted (Fig. 2; Sadler, 1961; Headford, 1962) probably because in these tubers the substrate becomes more quickly available for growth. Although during sprouting the availability of calcium is thought to limit sprout growth (Davies, 1984), between planting and emergence the availability of carbohydrates is more likely to restrict stem growth, as mineral nutrients could be absorbed during emergence (confirmed by unpublished data). Although the stems of lighter tubers were thinner (Fig. 3) and had lower weights at emergence (Fig. 4), the growth of these stems will have required a higher proportion of mother tuber reserves, because the stem:tuber ratio at emergence was considerably higher in plants from lighter tubers (Fig. 5; only fresh weight data available). Thus, if a similar proportion of tuber reserves becomes available each day for stem growth in all weight classes, stems from tubers with lower weights will emerge later because in total a higher proportion of the tuber reserves is necessary for emergence (cf. Fig. 5). This also implies that if plants from smaller tubers are damaged before or soon after emergence (e.g. by night frost) fewer reserves from the mother tuber (both absolutely and relatively) are available to resume growth.

The weight of the root system at emergence was lower in plants from lighter tubers (Fig. 4), but much more proportional to the weight of the mother tuber than that of the stem (Fig. 5). Consequently, in plants from lighter tubers the root system has to provide water and nutrients to a much larger shoot in relation to its weight (higher shoot:root ratio; Fig. 4). This may partly explain the slower foliar ground cover of plants from smaller tubers (Wiersema & Cabello, 1986; Struik & Lommen, 1990;

Allen et al., 1992) and - if this situation persists during further growth - it may render plants from small tubers more susceptible to drought and to second growth of progeny tubers, as reported by Struik & Lommen (1990). Because of the limited root system at emergence the use of small tubers may require special cultural techniques, such as fertilizer placement, irrigation, etc. to make full use of their potential.

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