Suppression of Mother Tuber Enlargement in the Sweet Potato Cultivar “Koganesengan” by Transplantation of Bottled Tuber Seedlings

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Abstract: Seed tubers of the sweet potato cultivar “Koganesengan” ranging from 40 to 70 g were cut in half at a right angle to the long axis. The half-cut tubers were planted in plastic wide-mouthed bottles, and the bottles were filled with a commercial soil mix. These bottled tubers were kept under natural sunlight in a glasshouse at 25ºC, and watered regularly. After 3–4 wk, the bottled tuber seedlings were transplanted to a field, leaving the tubers in the plastic bottles. Mother tuber enlargement was suppressed in the bottle, but daughter tubers were formed above the bottle, and the mother tuber yield was 4.5% of the total fresh yield of mother and daughter tubers. In the cultivation of tuber seedlings without bottling, the mother tuber yield was 11.2% of the total yield.

Key words: Bottled tuber seedling, Koganesengan, Mother tuber enlargement, Sweet potato, Transplant, Yield.

In Japan, sweet potato plants (Ipomoea batatas (L.) Lam.) are cultivated using the conventional sprouted-vine planting method. Direct planting of seed tubers has several advantages over conventional vine planting (Sakai, 1999), but has not been adopted widely. The tuber planting method, which was developed in the 1950s and 1960s, uses whole seed tubers (Kodama, 1962; Akita et al., 1962b). Kodama et al. (1957a, 1957b) studied the growth of sweet potato plants cultivated directly from seed tubers and reported that, during the early stages of growth, both the shoots and underground parts (roots and tubers) of these plants grew more rapidly than those of the plants generated by the vine-planting method. They also showed that the seed tubers planted in soil thickened into anomalous tubers. Akita and Kobayashi (1962) and Akita et al. (1962a) reported that the growth of directly planted seed tubers was inhibited by exposing them to light after sprouting. Ikemoto and Akita (1968) and Higashi et al. (1998) planted cut seed tubers, and examined the effect of this method on sprouting and yield (daughter and mother tubers). We previously reported that the transplantation of tuber seedlings derived from half-cut tubers resulted in enhanced yield compared to the conventional vine-planting cultivation method in the sweet potato cultivar “Murasakimasari” (Adachi et al., 2011). We also reported that the emergence percentage of enlargement of mother tubers and the dry matter weight of the mother tubers were lower when half-cut tuber seedlings were transplanted than when whole seed tubers were directly planted in “Murasakimasari”. In contrast, in cultivar “Koganesengan”, which is the most popular cultivar for sweet potato spirit production, transplantation of half-cut tuber seedlings resulted in mother tuber enlargement. The method, called tuber seedling transplantation (TST), was therefore unsuitable for use with this cultivar. Here, we report the cultivation of “Koganesengan” by an application of the TST method. We also describe a transplantation method for this cultivar using bottled tuber seedlings. In this method, mother tuber enlargement is physically suppressed by keeping the half-cut seed tubers in plastic bottles in the field.

Materials and Methods

1. Preparation of Half-Cut Tuber Seedlings

Seed tubers of the sweet potato cultivar “Koganesengan”, weighing from 20 to 50 g, were transversely cut into halves of 8 to 29 g with an average fresh weight ± standard deviation was 16 ± 4 g on 1 May 2008. We used 900 half-cut tuber seedlings...
tubers planted in plastic cell trays with a commercial soil mix (Napura Soil Mixes, Yanmar Co., Ltd.) on 1 May. Each 30 × 60 cm tray (Model 50AP-D, Tokan Kosan Co., Ltd.) consisted of 50 cells which measured 55 × 55 × 62.5 (height) mm each. The cut tubers in the cells were incubated for 3 to 4 wk in a glasshouse at 25°C under natural sunlight, to generate tuber seedlings (Adachi et al., 2011). Plants were watered daily or on alternate days, depending on the weather and the age of the seedlings.

2. Transplantation of Tuber Seedlings in 2008

The tuber seedlings of cultivar “Koganesengan” were transplanted to a field (latitude 31°45′N, longitude 131°01′E) at Miyakonojo Research Station, NARO Kyushu Okinawa Agricultural Research Center (NARO/KARC), Miyakonojo, Miyazaki Prefecture. The soil in the field was andosol, and the texture was loam (27.4% coarse sand, 35.1% fine sand, 27.3% silt, and 11.2% clay). Cattle manure and lime were applied at a rate of 20 t ha⁻¹ and 600 kg ha⁻¹, respectively. Chemical fertilizer consisting of N at 48 kg ha⁻¹, P₂O₅ at 72 kg ha⁻¹, and K₂O at 120 kg ha⁻¹ was also applied. High ridges were made with black plastic film mulch with a ridge distance of 90 cm and hill distance of 40 cm, making a planting density of 27,778 hills ha⁻¹. For comparison with tuber seedling transplanting (TST), conventional sprouted-vine planting (VP) was used in this experiment. In TST, well-developed tuber seedlings were selected and removed from the cell trays, and transplanted to the field at a depth of approximately 15 cm (Adachi et al., 2011). In the VP group, the sprouted vines, 38.3 ± 3.2 cm long with a stem length of 28.2 ± 4.2 cm (n = 20), were planted obliquely. The vine dry weight was 2.50 ± 0.72 g (n = 10). Both tuber seedlings and vines were planted under film mulch in 4 replicates on 22 May. The plants in an area (subplot) of 0.9 × 4 m (1 ridge with 10 plants) in each plot were harvested to examine yields. In these areas (subplots), there were no missing plants (vacant hills) in either the TST or VP group at harvest. The harvest date was 12 November. Therefore, the duration of cultivation was 174 d in both groups. Conventional measures were used for weed and pest controls.

At harvest, we examined (1) daughter tuber yield (tubers heavier than 50 g in fresh weight); (2) fresh weight of mother tubers; (3) total fresh yield of mother and daughter tubers; and (4) dry matter yield of shoots (leaves and stems).

3. Preparation of Bottled Tuber Seedlings

Seed tubers of the sweet potato cultivar “Koganesengan”, ranging from 40 to 70 g, were cut transversely and planted in plastic bottles on 21 May 2009. The range in fresh weight, the average fresh weight ± standard deviation, and the number of half-cut seed tubers were 15.0 ± 39.6 g, 25.3 ± 5.1 g, and 222, respectively. The plastic bottles used were 100 ml wide-mouthed bottles, measuring 75–89 mm in height, 48–50 mm in outside diameter, 32–36 mm in upper mouth inside diameter, and containing a 9 mm φ hole in the bottom, as shown in Fig. 1. Before planting the half-cut tubers in the bottles, small amounts of a commercial soil mix (Napura Soil Mixes, Yanmar Co., Ltd.) were poured into each bottle. Then, the half-cut seed tubers were planted in the bottles, and the bottles were filled with the soil mix. The tubers in the plastic bottles were incubated at 25°C in a glasshouse under natural sunlight, and watered daily or on alternate days, depending on the weather and age of the seedlings. Well-developed bottled tuber seedlings were transplanted to a field without removing the plastic bottles on 15 June (without bottling).

To determine the effect of the tuber bottling, we planted seed tubers in cell trays, following the same procedures described above (section 1). Seed tubers, ranging from 30 to 70 g in weight, were cut in half and planted on 21 May 2000. The fresh weight range, average fresh weight ± standard deviation, and the number of half-cut seed tubers were 12.7–40.2 g, 28.8 ± 5.1 g, and 250, respectively. Well-developed tuber seedlings were removed from the cell trays and transplanted to the field on 15 June (without bottling).

4. Cultivation by Transplanting Bottled Tuber Seedlings in 2009

The bottled tuber seedlings of cultivar “Koganesengan” were transplanted to an experimental field (latitude 31°45′N, longitude 131°01′E) at Miyakonojo Research Station, NARO/KARC. Manure was not applied. Lime was applied at a rate of 600 kg ha⁻¹. Chemical fertilizer consisting of N at 64 kg ha⁻¹, P₂O₅ at 96 kg ha⁻¹, and K₂O at 160 kg ha⁻¹ was applied. High ridges were made with black plastic film mulch (ridge distance 90 cm, hill distance 40 cm, and planting density 27,778 hills ha⁻¹). Three methods were used: BTST, transplanting bottled tuber seedlings (15 June); TST, transplanting tuber seedlings (15 June); and VP, conventional sprouted-vine planting (22 June). For BTST and TST, well-developed seedlings were selected, and transplanted at a depth of approximately 20 and 15 cm, respectively. In BTST, the tubers of seedlings were kept in the plastic bottles after transplanting. In VP, the sprouted vines, 42.3 ± 3.7 cm in length, with a stem length of 30.0 ± 3.8 cm, and vine dry weight of 1.34 ± 0.33 g (n = 10), were planted obliquely. The plants in an area (subplot) of 1.8 × 2 m (2 ridges, 10 plants) in each plot were harvested to examine the yields in the BTST and TST groups, while in the VP group, 20 plants were harvested. Each group was planted in 3 replicates. The percentages of missing plants (vacant hills) in the harvested subplots were 3.5%, 0% and 16.9% in BTST, TST and VP, respectively. This was due to wilting or stem rot of vines in VP. The
Fig. 1. Photograph of the plastic bottles used to hold the half-cut seed tubers. The half-cut seed tubers were placed inside the plastic bottles, and the bottles were filled with a commercial soil mix. The distance between the white lines is approximately 20 cm.

Fig. 2. The percentage of seedlings that emerged above the soil surface in the cell trays or the bottles. TS, tuber seedlings; BTS, bottled tuber seedlings. In all 3 experiments, a mixture of almost equal numbers of top and bottom halves of tubers were used.

Fig. 3. Photograph of the bottled tuber seedlings of cultivar “Koganesengan” at 24 DAP, and on the day before transplanting. The distance between the white lines is approximately 20 cm.

Fig. 4. Photograph of a stubble with daughter tubers and a bottled mother tuber in the BTST plot at harvest. The distance between white lines is approximately 20 cm.

Fig. 6. Photographs of mother tubers in the BTST plot (A) and the TST plot (B) at harvest. In BTST (A), plastic bottles were removed before taking the photograph. The distance between white lines is approximately 20 cm.
harvest date was 25 November. Therefore, the cultivation duration was 163 d in both BTST and TST, and 156 d in VP. Conventional weed and pest control measures were applied during the cultivation period. The same yield properties as described in section 2 were determined.

Results

1. Preparation of Tuber Seedlings

Seedling emergence from half-cut seed tubers planted in cell trays was examined in 2008. The tubers used were a mixture of almost equal numbers of top and bottom halves. At 6 days after planting (DAP), the first seedlings emerged above the surface. Fig. 2 shows the percentages of seedling emergence. At 10 DAP, the seedling emergence was approximately 40%. This increased to 70% at 13 DAP, and to approximately 95% at 21 DAP. These seedlings from the half-cut tubers were therefore transplanted 3–4 wk after planting.

2. Cultivation by Transplantation of Tuber Seedlings (TST) in 2008

Table 1 shows the fresh daughter tuber yield, the fresh mother tuber yield, total fresh yield of mother and daughter tubers, and the percentage of mother tuber yield to total fresh tuber yield in TST and VP.

There was no significant difference between the fresh daughter tuber yields in the TST and VP groups, although the yield in TST tended to be higher than in VP. On the other hand, the total fresh yield of mother and daughter tubers in TST was significantly higher than in VP (at the 1% level). The shoot dry matter yield in TST (344±37 g m⁻²) was significantly higher than that in VP (224±16 g m⁻²) at the 1% level. In TST, the mother tubers enlarged and occupied 12.1% of the total fresh tuber yield. The individual fresh weight of mother tubers in TST varied greatly ranging from 0 to 1232.4 g, and the average fresh weight ± standard deviation was 339.8 ± 239.8 g (n = 40).

3. Preparation of Bottled Tuber Seedlings

A mixture of almost equal numbers of top and bottom halves of tubers were bottled. Although the seedling emergence from the bottled tubers was approximately 3 d later than that from the tubers planted in cell trays, the seedling emergence in bottled tuber seedlings reached 97% at 31 DAP. The bottled tuber seedlings at 24 DAP (Fig. 2, Fig. 3) were transplanted to the field. The differences between the seedling emergence curves in 2008 and 2009 may be related to differences in the vitality of the seed tubers.

4. Cultivation by Transplantation of Bottled Tuber Seedlings (BTST) in 2009

At harvest, mother tuber enlargement was suppressed in the BTST group by the plastic confinement of the bottles around the mother tubers. Daughter tubers were formed above the bottle (Fig. 4). There were no significant differences between the BTST, TST and VP groups in the fresh daughter tuber yields or in the total fresh yield of mother and daughter tubers (Table 2). However, when we examined mother tuber enlargement in the areas surrounding the yield survey subplots (30 plants × 3 replications, 27 November, 2 d after the date of the yield survey), the fresh weight of the mother tuber per plant in the BTST group was significantly lighter than that in the TST group at the 5% level (Fig. 5, Fig. 6). The average fresh weight ± standard deviation, individual fresh weight range, and total number of mother tubers examined were 63 ± 11 g, 1–161 g, and 89, respectively in BTST, and

| Treatment | Fresh daughter tuber yield (g m⁻²) | Fresh mother tuber yield (g m⁻²) | Total fresh tuber yield (mother and daughter tubers) (g m⁻²) | Percentage of mother tuber yield over total fresh tuber yield (%) |
|-----------|-----------------------------------|---------------------------------|-------------------------------------------------------------|---------------------------------------------------------------|
| BTST      | 3182 ± 638                         | 150 ± 34                        | 3332 ± 637                                                   | 4.5                                                          |
| TST       | 3017 ± 361                         | 382 ± 186                       | 3399 ± 259                                                   | 11.2                                                         |
| VP        | 2924 ± 267                         | –                               | 2924 ± 267                                                   | –                                                            |

Values reflect the average ± standard deviation of 4 replicates. Daughter tubers of more than 50 g in fresh weight were included only.

| Treatment | Fresh daughter tuber yield (g m⁻²) | Fresh mother tuber yield (g m⁻²) | Total fresh tuber yield (mother and daughter tubers) (g m⁻²) | Percentage of mother tuber yield over total fresh tuber yield (%) |
|-----------|-----------------------------------|---------------------------------|-------------------------------------------------------------|---------------------------------------------------------------|
| BTST      | 3398 ± 511                         | 549 ± 217                       | 4534 ± 306                                                   | 12.1                                                          |
| TST       | 3756 ± 64                          | –                               | 3756 ± 64                                                    | –                                                            |

Values reflect the average ± standard deviation of 3 replicates. Daughter tubers of more than 50 g in fresh weight were included only.
results of cultivation mode and year on the total yields of mother and daughter tubers were statistically significant at the 1% and 0.1% levels, respectively, but the interaction effect between the cultivation mode and year was not significant (Table 3). This means that the total yield of mother and daughter tubers was higher in TST than in VP in sweet potato cultivar “Koganesengan”, and that the total tuber yield in 2008 was higher than that in 2009. On the other hand, the effect of cultivation mode on the daughter tuber yields was not significant, although the effect of year was significant at the 1% level (Table 3).

Because the mother tuber enlargement competes with daughter tuber enlargement (thickening) for allocation of photosynthates, the daughter tuber yield may be suppressed by the mother tuber enlargement in the TST method.

## Discussion

In the experiment in 2008, the mother tubers enlarged to 12.1% of the total fresh tuber yield in the TST cultivation method in the cultivar “Koganesengan”. The mother tubers in TST plots were anomalous and deformed in shape, and their quality was inferior to that of the daughter tubers. Therefore, the mother tubers are not suitable for the fermentation industry. The farmers have to separate the mother tubers from the harvested tubers and discard them. Because of the labor and the cost of these procedures, over 10% of the mother tuber yield to the total tuber yield would not be acceptable, and the TST method would not be suitable for this cultivar.

Two-factor ANOVA (Table 3) showed that the TST method enhanced total tuber yield over the conventional VP method in cultivar “Koganesengan”. In cultivar “Murasakimasari”, TST cultivation produced higher yield of daughter tubers than the conventional VP, and the percentages of mother tuber fresh weights over the total fresh tuber yields in TST were 2.0% and 3.3% in the 2008 field experiment (Adachi et al., 2011), and 1.2% and 0.9% in the 2009 farmer’s field experiment (personal communication). These percentages were clearly lower than those in the cultivar “Koganesengan” (Table 1, Table 2). Hence, in “Koganesengan”, control of mother tuber enlargement is important in the TST method.

In BTST cultivation, the plastic bottles physically...
suppress mother tuber enlargement, and the mother tuber yield was 4.5% of the total fresh tuber yield of the cultivar “Koganesengan” in the 2009 field experiment. In TST cultivation, however, the mother tuber yield was 11.2% of the total yield in 2009.

The BTST method is still in a preliminary stage of development, because we used wide-mouthed plastic bottles designed for lab-use, and made holes in the bottom for water drainage. The shape and size of the container should be modified for optimal suppression of mother tuber yield. In this way, the yield of daughter tubers can be increased due to efficient allocation of photosynthates to the daughter tubers. In future studies, the shape and material of the container should be examined to obtain the optimal type. The BTST method has the potential to enhance daughter tuber yield even further, by improving the bottle shape, manuring practices, and management of seed tuber activity.

The present study demonstrated that the BTST method is effective for the cultivar “Koganesengan”, and this method may be useful for cultivation of sweet potato. In BTST cultivation, the plastic bottles have to be collected at harvest, and can be reused the next year, although some may have to be discarded because of decay. Because the bottle’s condition at harvest depends on its structure and material, it is necessary to elucidate the optimal container’s type and estimate the labor and the cost in the BTST method including the collection and reuse of bottles compared with the conventional VP method.

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* In Japanese with English summary.
** In Japanese with English title.
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