Introduction

Sweetpotato (*Ipomoea batatas* Lam.) lines with erect plant type (abbreviated as ER-type), also known as dwarf sweetpotato lines, have advantages. One advantage is the simplicity of cultivation. Vines of ER-type sweetpotato lines are short and suitable for machine transplanting. Another advantage is that weeds growing between rows can be removed by machinery since the inter-row space is not covered by vines, as is the case with normal spreading lines. Moreover, sweetpotato cultivars of a vigorous ER-type are less affected by weeds than cultivars of a spreading plant type (Harrison and Jackson 2011). In addition, ER-type sweetpotatoes are suitable for a kitchen garden because their vines do not grow extensively, facilitating cultivation in a limited space. However, only a few cultivars with ER-type growth habit have been bred in Japan, such as ‘Tsurusengan’ (Shiga et al. 1983) for feed use and ‘Tama-akane’ (Sakai 2009) for brewing. ‘Benikomachi’ (Sakai et al. 1978), bred for table use, possesses short, thick vines and is classified as a compact plant type (Tarumoto et al. 1992). In spite of the high palatability of its storage roots, the cultivation area of ‘Benikomachi’ is very limited due to the irregular shape of its storage roots and its susceptibility to stem rot. An ER-type sweetpotato line may be marketable if these drawbacks are minimized. So, it is important to improve agronomic characteristics of ER-type lines.

Field trials revealed that ER-type sweetpotato lines were not as competitive as normal lines and they were eliminated during the selection process (Sakai and Sirasaka 1957). Hence, the selection of seedlings should not be focused on yield in preliminary small-scale trials. Field performance tests for ER-type lines should be carried out in sufficiently large plots with at least four rows, in order to estimate yield correctly (Sakai and Sirasaka 1957).

Generally, cross breeding using ER-type parent lines has been used to breed ER-type cultivars (Toyama et al. 2004, 2005). On the other hand, the mutation breeding method could be useful because new ER-type lines with good agronomic traits could be bred in a short amount of time by mutating major cultivars.

In this study, both breeding methods were used to develop ER-type sweetpotato lines. We then checked the productivity and quality characteristics of the new lines to select ones that were practical. Furthermore, we tested a new index (plant height/plant width ratio) that would be useful in the selection of plant type.

Breeding erect plant type sweetpotato lines using cross breeding and gamma-ray irradiation

Toshikazu Kuranouchi*1), Tadashi Kumazaki1,2), Toru Kumagai1) and Makoto Nakatani1,3)

1) NARO Institute of Crop Science, 2-1-2 Kannondai, Tsukuba, Ibaraki 305-8518, Japan
2) Present address: Toyohashi University of Technology, 1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi 441-8580, Japan
3) Present address: Secretariat of Agriculture, Forestry and Fisheries Research Council, Ministry of Agriculture, Forestry and Fisheries of Japan, Chiyoda-ku, Tokyo 100-8950, Japan

Few sweetpotato (*Ipomoea batatas* Lam.) cultivars with erect plant type are available despite their advantages over spreading type, such as simplicity of cultivation and ability to adapt to limited space. One of the reasons is insufficiency of their agronomic characteristics for table use. So, it is important to overcome these drawbacks of ER-type lines. We attempted to breed new erect plant type sweetpotato lines having good agronomic traits using cross breeding and mutation breeding with gamma-ray irradiation. With cross breeding we successfully developed new erect plant type lines with almost equal levels of yield as compared to ‘Beniazuma’, one of the leading cultivars in Japan. However, mutation breeding failed to develop any promising lines because we could not obtain distinct erect plant type lines. In the future larger numbers of plants should be used for mutation breeding, and irradiation methods should be improved.

Key Words: sweetpotato, erect plant type, dwarf plant type, gamma-ray irradiation.
Breeding Erect Plant Type Sweetpotato Lines

We distinguished seven plant types; 1: very erect; 2: erect; 3: compact; 4: semi-compact; 5: moderate; 6: semi-spreading; and 7: spreading (Tarumoto et al. 1992). The detailed description of these plant types is shown in Table 1. We judged plant type index of ‘Beniazuma’ in early-July to mid-July for 5 (moderate) and the index slightly increased after August by the elongation of vines. Plants with indices lower than four were defined as ‘ER-type’ and used for screening.

Different plant types of lines are shown in Fig. 1.

I. Breeding of ER-type sweetpotato lines by cross breeding

Cross breeding using ER-type sweetpotato germplasm was initiated in 2000 in the glasshouses of the National Agriculture Research Center (Tsukubamirai, Ibaraki) and the National Agricultural Research Center for Kyushu Okinawa Region, Japan (Miyakonojo, Miyazaki). The characteristics of parent lines/cultivars are summarized in Table 1. Starting in 2007, we used parent lines possessing good agronomic traits to breed the practical lines. The breeding process consisted of four steps, as follows.

Year 1 (selection of seedlings): Seeds were sown in the nursery beds in late-March. Vines were cut from the seedlings in mid-May and vertically transplanted to an experimental field (Tsukubamirai, Ibaraki). They were planted in rows, with intervals of 25 cm between plants and 100 cm between rows. The rows were covered with plastic film mulch. Before transplanting, 60 g m⁻² of chemical fertilizer (3N-12P-10K) was applied. The amount of chemical fertilizer was reduced to 40 g m⁻² starting in 2007. In mid-July, plant type was checked, and ER-type individuals were marked and selected. At the end of October, storage roots were harvested, and further selection was made based on the root shape of each plant. Plants with irregular root shape were excluded.

Year 2: In mid-March, selected storage roots were planted individually in a nursery bed. Eight to ten vines per storage root were cut and planted in the experimental field. The cultivation methods from year 1 were used. Plant type was determined in mid-July. Storage roots were harvested and selected for quality in mid-October and the lines were designated.

Year 3: Five storage roots per line were planted in a nursery bed. Thirty-two vines were obtained from each line and planted in the field. Each experimental plot consisted of four rows, each with eight plants. The cultivation conditions and schedule from year 1 were used. Some ER-type lines found in the breeding program for table and processing use were also included.

Year 4 and after: All experimental procedures were the same as years 2 and 3, except there were two replications. ER-type lines were selected for table use and processing.

Fig. 1. Different plant types of sweetpotato lines. A: Erect (Plant type index: 2), B: Moderate (Plant type index: 5). Photos were taken on 22 July 2011 in Tsukubamirai, Ibaraki.

Table 1. Plant type and traits of parent lines/cultivars and Japanese standard cultivar ‘Beniazuma’

| Lines and cultivars | Plant type index | Storage root weight (kg a⁻¹) | Average weight of a storage root (g) | Taste of steamed root | Division | Experimental year |
|---------------------|-----------------|------------------------------|-------------------------------------|-----------------------|----------|-------------------|
| Boniato 14          | 1               | 7.0                          | 30.0                                | moderate              | introduced line | 174863           |
| Tsurusengan         | 3               | 10.7                         | 34.0                                | moderate              | bred cultivar  | 168605           |
| Benikomachi         | 3               | 5.0                          | 28.8                                | moderate              | bred cultivar  | 168603           |
| Tokyokintoki        | 3               |                              |                                     |                       | native line     | –                 |
| Beniazuma           | 5               | 4.3                          | 18.0                                | moderate–moderately good | bred cultivar  | 168606           |
| Beniharuka          | 4               | 342                          | 195                                 | moderately good       | bred cultivar  | 2014              |
| Tama-akane          | 3               | 520                          | 156                                 | moderate              | bred cultivar  | 2010              |
| Himeryaka           | 4               | 301                          | 160                                 | moderately good       | bred cultivar  | 2010              |
| Kanto No. 134       | 3               | 262                          | 197                                 | moderate              | bred line      | 2010              |
| Beniazuma           | 5               | 371                          | 267                                 | moderate–moderately good | bred cultivar  | 2010              |

Notes:
1: very erect (Internode length and vine length are very short. Vines grow vertically.); 2: erect (Internode length and vine length are short. Vines grow nearly vertically.); 3: compact (Internode length and vine length are short. Vines grow slant ways.); 4: semi-compact (The middle of compact and moderate.); 5: moderate (Internode length and vine length are moderate. Vines grow nearly horizontally.); 6: semi-spreading (The middle of moderate and spreading.); 7: spreading (Internode length and vine length are long. Vines grow horizontally.).

2 Number of primary branches longer than 1 cm.

3 Accession number of NIAS Genebank, Japan.

The investigation of plant type index, primary branches, plant height and plant width were carried out on early-July 2001.
use. The plant height and the plant width were measured in July, three times from 2013 to 2014. The plant height was the length from the plant foot to the tip of the highest leaf, and the plant width was the distance that was the longest between the tips of the vines.

2. Breeding through mutation by gamma-ray irradiation

Cultivars and lines that received gamma-ray irradiation were ‘Beniazuma’ (irradiated in 2006 and 2007), ‘Purple Sweet Lord’ (2006), ‘Quick Sweet’ (2007), and ‘Himeayaka’ (2006 and 2007).

Gamma-ray irradiation was conducted at the Institute of Radiation Breeding (National Institute of Agrobiological Sciences) in mid-June. In 2006, two doses of gamma-ray irradiation (2 and 10 Gy hr\(^{-1}\)) were applied to sweetpotato vines for 20 hours. Each vine received 5 Gy hr\(^{-1}\) of gamma-ray irradiation for 20 hours in 2007. Vines were planted in the field immediately after treatment (Tsukubamirai, Ibaraki). Cultivation methods followed the methods used for cross breeding. The vines were examined for plant type and bud growth. Mutated plants were visually selected.

Vines of selected plants were planted in pots and grown in a glasshouse. A maximum of 20 vines per plant were cut and planted in the field in late-May of the following year. Cultivation conditions were the same as the previous year. Plant type was evaluated in mid-July. Storage roots were harvested and yield characteristics were investigated in late-October.

Results

1. Cross breeding

(1) Breeding trials in 2001–2003

The plant type of the seedlings from each cross was determined in 2001 and is summarized in Table 2. Although growth habit of the seedlings tended to be spreading type rather than ER-type, erect type offspring (plant type 2) also segregated from crosses even when both parents were of compact type (plant type 3). Some crosses produced moderate type offsprings (plant type 5), but no semi spreading type plants (plant type 6) were produced.

Seedlings of plant type 2, in addition to type 3 seedlings with good root shape, were selected and evaluated again for their growth habit in 2002. The plant type of the offsprings was almost unchanged (nine lines remained unchanged; four declined, and one improved).

Lines ‘00S01-21’ (plant type 3) and ‘00S04-10’ (plant type 4) were selected and compared with the leading cultivars, ‘Beniazuma’ and ‘Kokei No. 14’, for table use characteristics, in 2003. These lines were inferior to ‘Beniazuma’ in yield and taste.

(2) Breeding trials in 2008–2013

The ER-type seedlings were selected from the 2008 to 2010 trials. These seedlings were used for further selection the next year. The segregating rate of ER-type seedlings in 2008 was 4.4% (40 ER-type/899 all) when ER-type parents were used. On the other hand, only 1.0% (108 ER-type/10,593 all) ER-type seedlings were obtained from the crosses between non-ER-type parents. Selection rate was low in 2008, 0.2% (18 seedlings were selected from 11492 seedlings) since seedlings from non-ER-type parents were included. From 2009 to 2010, the selection rates were higher than in 2008 and were 8.7% and 4.6% respectively. These seeds were obtained from the crosses using ER-type parents.

Erect-type lines ‘07074-1d’, ‘08138-20d’, and ‘09121-16d’ were selected from the seedlings and compared with reference cultivars and lines, in terms of their important traits (Table 3).

Line ‘07074-1d’, originating from a cross between ‘Beniharuka’ and ‘Tama-akane’ (compact plant type), was estimated as an ER-type line in seedling selection in 2008, and was subjected to a performance test in 2009. As a result, the plant type index of this line was determined to be 2.4 (mid-July) and it was selected as a promising ER-type line (Fig. 2). Line ‘07074-1d’ remained erect until its late growth stage. The taste of the steamed roots was moderate.

Line ‘08138-20d’, originating from a cross between ‘Himeayaka’ and ‘Tama-akane’, was estimated as an ER-type line in seedling selection in 2009, and was subjected to a performance test in 2010. As a result, the plant type index

| Cross designation | Seed parent | Pollen parent | No. of seedings | No. of seedlings in each plant type* | Average of all seedlings | No. of selected seedlings | Average of selected seedlings |
|-------------------|-------------|---------------|-----------------|-------------------------------------|--------------------------|---------------------------|-------------------------------|
| 00S01             | Boniato-14 (1) | Benikomachi (3) | 29              | 0 15 10 4 0 0                       | 2.6 ± 0.7                | 3                         | 2.0                           |
| 00S02             | Benikomachi (3) | Boniato-14 (1) | 10              | 0 6 4 0 0 0                        | 2.4 ± 0.5                | 1                         | 2.0                           |
| 00S03             | Boniato-14 (1) | Tsurusengan (3) | 28              | 0 15 13 0 0 0                      | 2.5 ± 0.5                | 4                         | 2.3                           |
| 00S04             | Tsurusengan (3) | Benikomachi (3) | 65              | 0 22 30 13 0 0                     | 2.9 ± 0.7                | 4                         | 2.3                           |
| 00S05             | Benikomachi (3) | Tokyokintoki (3) | 14              | 2 7 5 0 0 0                        | 3.2 ± 0.7                | 2                         | 2.5                           |
| 00S06             | Tokyokintoki (3) | Benikomachi (3) | 15              | 0 2 9 4 0 0                        | 3.1 ± 0.6                | 1                         | 2.0                           |
| 00S07             | Tsurusengan (3) | Tokyokintoki (3) | 29              | 0 7 15 5 2 0                       | 3.1 ± 0.8                | 1                         | 2.0                           |
| 00S08             | Tokyokintoki (3) | Tsurusengan (3) | 23              | 0 5 11 6 1 0                       | 3.1 ± 0.8                | 2                         | 2.5                           |

*: very erect to 7: spreading, see Table 1.  
Figures in parentheses indicate plant type on early-July 2001.  
Average data are shown as average ± standard deviation.  
The investigation was carried out on 6 July 2001.
Breeding erect plant type sweetpotato lines

Breeding Science
Vol. 66 No. 3

459

Fig. 2. Growth habit of the erect-plant type line ‘07074-1d’ (right) and the leading cultivar for table use, ‘Beniazuma’ (left). Photos were taken on 10 July 2013 in Tsukubamirai, Ibaraki.

of this line was determined to be 3.0 (mid-July) and it was selected as an ER-type line. This line contains carotenoid in the roots, and the taste of the steamed roots was moderately good.

Line ‘09121-16d’, originating from a cross between ‘Kanto No. 134’ and ‘Tama-akane’, was estimated as an ER-type line in seedling selection in 2010, and was subject- ed to a performance test in 2011. As a result, the plant type index of this line was determined to be 3.0 (mid-July) and it was selected as an ER-type line. The taste of the steamed roots was moderate to moderately good.

The yields of these three ER-type lines were almost equal to that of ‘Kyukei 281’ in early-July, while that of ‘Beniazuma’ was almost half (Fig. 3). The plant height of all lines were elongated in mid-July, especially in ‘09121-16d’. The plant width (PW) of these ER-type lines was almost equal to that of ‘Kyukei 281’. The plant width of the lines increased approximately two fold in mid-July, but the elongation was not clear in ‘07074-1d’. On the other hand, it was very clear in ‘Beniazuma’, the standard cultivar.

The PH/PW ratio of these ER-type lines was almost 0.5 in early-July and equal to that of ‘Kyukei 281’. The plant type index of this line was determined to be 3.0 (mid-July) and it was selected as an ER-type line. This line contains carotenoid in the roots, and the taste of the steamed roots was moderately good.

2. Mutation breeding through gamma-ray irradiation

Only a few plants were selected from all of the cultivars (Table 4) since gamma-ray irradiation resulted in growth inhibition and deformity of leaves. The influence was obvious in plants that received radiation of more than 100 Gy. When ‘Purple Sweet Lord’ received 200 Gy radiation, more than 90% of the plants were negatively affected, showing limited growth or death. When ‘Beniazuma’ and ‘Purple Sweet Lord’ received 40 Gy radiation, no plant was selected as ER-type. Vines of some plants were selected from 4 cultivars respectively to examine plant type. Variability in plant type was not observed within plants from any cultivars. We could not recognize typical chimera plant.

Plant type and yield of the lines selected in 2006 and 2007 were investigated from 2008 to 2010 in the field. Plant type index was at first scored lower by 1 to 2 in the selected lines than in their original cultivars/lines but they became indistinguishable until the late growth stage (Table 5). The selected lines were inferior in yield to their original cultivars/lines except the lines selected from ‘Himeayaka’ in 2007.

Table 3. Yield and taste of the steamed roots of erect-compact type sweetpotato lines

| Year   | Cultivars and lines | Plant type index<sup>a</sup> | Storage root weight<sup>b</sup> (kg a<sup>−1</sup>) | Average weight of a storage root (g) | Characteristics of steamed roots |
|--------|---------------------|-------------------------------|-----------------------------------------------|----------------------------------|----------------------------------|
| 2011–2014 | 07074-1d          | 2.4 ± 0.4 2.5 ± 0.4          | 299 ± 50                                      | 140 ± 22 light yellow white    | moderately mealy moderate       |
|        | Beniazuma          | 5.0 ± 0.0 5.0 ± 0.0          | 290 ± 21                                      | 222 ± 25 light yellow white    | moderately mealy moderate       |
|        | Kyukei 281         | 2.6 ± 0.4 2.8 ± 0.2          | 175 ± 25                                      | 113 ± 17 yellow white          | moderate                       |
| 2012–2014 | 08138-20d         | 3.0 ± 0.0 3.2 ± 0.2          | 286 ± 12                                      | 157 ± 16 light orange         | moderate–moderately mealy       |
|        | Beniazuma          | 5.0 ± 0.0 5.0 ± 0.0          | 301 ± 11                                      | 234 ± 15 light yellow white    | moderately mealy moderate       |
|        | Kyukei 281         | 2.5 ± 0.4 2.8 ± 0.2          | 172 ± 28                                      | 119 ± 15 yellow white          | moderate                       |
| 2013–2014 | 09121-16d         | 3.0 ± 0.0 4.0 ± 0.0          | 333 ± 53                                      | 119 ± 14 yellow white         | moderate–moderately good        |
|        | Beniazuma          | 5.0 ± 0.0 5.0 ± 0.0          | 308 ± 5                                       | 225 ± 7 light yellow          | moderately mealy moderately good|
|        | Kyukei 281         | 2.5 ± 0.5 3.0 ± 0.0          | 154 ± 14                                      | 110 ± 10 yellow–yellow white  | moderate                       |

<sup>a</sup>1: very erect to 7: spreading, see Table 1. The investigation was carried out on mid-July (early) and early-August (late).

<sup>b</sup>Roots weighing less than 50 g were eliminated.

<sup>c</sup>sticky, moderately sticky, moderate, moderately mealy, mealy.

<sup>d</sup>poor, moderately poor, moderate, moderately good, good.

Average data are shown as average ± standard deviation in each trial years. 32 plants were planted in each experimental plot.

459
Discussion

ER-type sweetpotatoes could be developed for both table use and processing, since we found some promising lines in the breeding program. Breeding of sweetpotatoes has emphasized the root characteristics but not the plant type. Yamakawa and Sakamoto (1978) investigated the effect of seedling lines on plant type and found that ER-type offspring occurred only rarely. We found the same trend in the crosses between erect/compact parents and spreading ones, but confirmed that the ER-type were more likely to occur from crosses using these ER-type parents than from crosses between non-ER-type parents. These findings indicate the need to choose the right parents. We have selected some promising lines from the progenies of some new Japanese cultivars, for example, ‘Beniharuka’, ‘Himeayaka’, and ‘Tama-akane’. It is important to use parent lines that possess good agronomic traits.

As Sakai and Sirasaka (1957) pointed out, erect seedlings should be carefully selected since they are not as competitive as spreading ones. McLaurin and Kays (1993) grafted five vine length types onto the same rootstock to investigate the relationship between plant type and yield. They found that yield was low in the erect plant type. Sakamoto (1984) reported that vegetative growth in the early stage was related to plant type. On the other hand, Yamakawa and Sakamoto (1978) suggested that breeding ER-type sweetpotato lines with a high yield is possible through the selection of plants with a high growth rate in the early stage. We successfully developed erect/compact type lines with almost equal levels of yield as ‘Beniazuma’, the leading cultivar for table use. Therefore, it is possible to breed high quality ER-type cultivars with high root yield.

The judgement of plant type index should be done in early-July to mid-July because of elongation of vines after August. We selected the ER-type lines using the plant type index, but it may be possible to select lines more clearly using the PH/PW ratio, because the PH/PW ratio indicates the difference of plant type between ER-type plant and non-ER-type plant objectively, and the ratios of ER-type plants are generally stable from early-July to mid-July. Further examination is needed to confirm the effect of screening using the PH/PW ratio.

ER-type sweetpotatoes, such as ‘Tsurunasi-genzi’ and ‘Tachi-kagoshima’ were presumably bred through mutation of native cultivars at the beginning of the 19th century (Fujise 1965). Spontaneous mutation is less likely to produce erect

Table 4. Change in growth type after gamma-ray irradiation and the number of selected plants

| Year | Cultivars     | Amount of irradiation (Gy) | No. of vines | Types of growth                     | No. of selected plants |
|------|--------------|----------------------------|--------------|-------------------------------------|------------------------|
|      |              |                            |              | Almost normal                       |                        |
|      |              |                            |              | Stopped or dead                      |                        |
| 2006 | Beniazuma    | 40                         | 100          | 95                                  | 5                      |
|      |              | 200                        | 100          | 53                                  | 47                     |
|      | Purple Sweet Lord | 40                        | 96           | 93                                  | 3                      |
|      |              | 200                        | 98           | 6                                   | 92                     |
|      | Himeayaka    | 200                        | 201          | 87                                  | 114                    |
| 2007 | Beniazuma    | 100                        | 187          | 66                                  | 121                    |
|      | Quick Sweet  | 100                        | 190          | 137                                 | 53                     |
|      | Himeayaka    | 100                        | 188          | 98                                  | 90                     |

Fig. 3. Plant height (PH), plant width (PW) and PH/PW ratio of selected lines. The investigation was carried out in early- mid-July in 2013–2014. Error bars indicate standard deviations. 6 plants were observed in each plot.
Breeding erect plant type sweetpotato lines

Breeding Science
Vol. 66 No. 3

461

plant type. We used gamma-ray irradiation and we could not find any promising ER-type plants using a limited number of plant materials, but we obtained some moderately erect plants. When the plants received 40 Gy radiation, no plant was selected. So, there is a possibility that the plants must receive more radiation to obtain ER-type lines. We did not distinguish each bud of irradiated plants, but it might be necessary to do that to obtain ER-type plants efficiently. In the future, larger numbers of plants should be used and irradiation methods should be improved to obtain ER-type lines.

The elongation of vines and petioles is regulated by different physiological and morphological systems (Suge 1979). We failed to find plants with short petioles in ER-type lines. Elongation of the petioles should contribute to the three dimensional position of leaves allowing for more efficient photosynthesis, especially in ER-type lines. These lines would be expected to also have the potential for high yield and good quality making them marketable.

Acknowledgements

We thank the support staff of the NARO Agricultural Research Center for their technical assistance. We also thank the support staff of the Sweetpotato laboratory in the NARO Institute of Crop Science. We thank Dr. Masumi Katsuta, Dr. Naoyuki Matsumoto, and Dr. Kenji Katayama for critical reading of the manuscript.

Table 5. Yield of the selected lines created with gamma-ray irradiation

| Year       | Cultivars and lines | Plant type index | Storage root weight (kg a⁻¹) | Average weight of a root (g) |
|------------|---------------------|------------------|-------------------------------|------------------------------|
| 2008–2009  | Beniazuma 06Gy-1    | 4.0, 5.0          | 272                           | 222                          |
| 2009–2010  | Beniazuma 07Gy-1    | 3.5, 4.5          | 196                           | 126                          |
| 2008, 2010 | Beniazuma (original)| 4.0, 5.0          | 231                           | 123                          |
| 2009–2010  | Himeayaka 06Gy-1    | 4.0, 5.0          | 196                           | 126                          |
| 2009–2010  | Himeayaka (original)| 4.0, 5.0          | 231                           | 123                          |
| 2008       | Purple Sweet Lord   | 4.0, 5.0          | 198                           | 127                          |
| 2009       | Quick Sweet 07Gy-1  | 4.0, 4.0          | 291                           | 264                          |

* 06 GY: Irradiated in 2006. 07 GY: Irradiated in 2007.
* 1: very erect to 7: spreading, see Table 1.

Early: estimated in early-July; Late: estimated in early-August to mid-October.

Literature Cited

Fujise, K. (1965) Spontaneous mutation and its use in sweet potato. Gamma Field Symposia 4: 43–53.
Harrison, H.F. and D.M. Jackson (2011) Response of two sweet potato cultivars to weed interference. Crop Protection 30: 1291–1296.
McLaurin, W.J. and S.J. Kays (1993) Sweetpotato canopy geometry. Hortscience 28: 458.
Sakai, K. and S. Sirasaka (1957) Effect of the competition among different types of sweet potato varieties on the top and tuber yield. Bull. Kyushu Agr. Expt. Sta. 5: 173–191.
Sakai, K., T. Ando, H. Ishikawa, T. Takemata and M. Umehara (1978) On a new sweet potato variety ‘BENIKOMACHI’. J. Cent. Agr. Expt. Sta. 27: 57–68.
Sakai, T. (2009) ‘Tamaakane’ (for processing, for ’syochu’, 2009) imorui shinoyojoho 101: 13–17.
Sakamoto, S. (1984) Classification of plant type and relationship between plant type and tuber yield on sweet potato. Kyushu Agr. Res. 46: 51.
Shiga, T., T. Ando, K. Sakai, T. Takemata, H. Ishikawa and M. Umehara (1983) A new sweet potato cultivar ‘TSURU-SENGAN’. Bull. Natl. Agr. Res. Cent. 1: 9–35.
Suge, H. (1979) Gibberellin relationships in a dwarf mutant of sweet potato. Japan. J. Genetics 54: 35–42.
Tarumoto, I., T. Takemata and T. Yuno (1992) Origin and character of sweet potato germplasms preserved in National Agriculture Research Center, and literatures of sweet potato in Ibusuki city library. Misc. Natl. Agr. Res. Cent. 23: 1–157.
Toyama, J., T. Kumagai, O. Yamakawa and Y. Nakazawa (2004) Dwarf plant experiment. Ann. Rep. of Sweetpotato Breed. Res. 14: 147–148.
Toyama, J., Y. Kai, O. Yamakawa and M. Yoshinaga (2005) Dwarf plant experiment. Ann. Rep. of Sweetpotato Breed. Res. 15: 102–104.
Yamakawa, O. and S. Sakamoto (1978) Characteristics of the vine in the early stage of sweetpotato and its relation to characteristics of the roots in the harvest season. Kyushu Agr. Res. 40: 52.