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Holding of Cut-sprouts in Sweet Potato (*Ipomoea batatas* Lam.)

I. Effects of holding on rooting of cut-sprouts*

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TSUNO and FUJISE[12] have suggested that the delay of early growth after transplanting may be one of the limiting factors in the dry matter production and yield in sweet potato (*Ipomoea batatas* Lam.). It is important for increasing the dry matter production and yield to accelerate the rooting and establishment of cut-sprouts after transplanting. Especially in the early harvest culture for marketable products high yield and quality of tubers depend largely on fast rooting and proper establishment of cut-sprouts.

It is noteworthy that sweet potato growers often transplant the cut-sprouts to their fields a few days after cutting. In many cases the holding of cut-sprouts is carried out in a shed, storeroom for seed tubers or under the shade of evergreen trees. In general it is believed that this technique is applied in order to be able to transplant when busy farming activities or adverse weather and soil conditions are over.

In sweet potato, however, there are few reports on experimental studies on the holding or storage of cut-sprouts. KAMATANI[6] showed that the rooting ability of cut-sprouts did not decrease for 6 days during the holding period. Recently HALL[3], HAMMETT[4] and HAMMETT[5] have demonstrated that the tuber yield was increased by the holding of cuttings for 3—7 days at 13—16°C. However the effects of holding on rooting or establishment of cut-sprouts have not been clarified.

In this report we investigated the effect of holding on the rooting of cut-sprouts in a controlled environment to obtain accurate information on the acceleration effects on the rooting and establishment of cut-sprouts.

Materials and Methods

Experiments were carried out twice in Sept. 1983 and June 1985.

1. *Plant materials*

In 1983 the cultivar Koganesengan and in 1985 two cultivars i.e. Koganesengan and Kokei No.14 were used as the experimental materials. In both experiments cut-sprouts with 7 unfolding leaves were removed from bedded tuberous roots in an electric hotbed on 27 Sept., 1983 and 19 June, 1985 at the same time for all the treatments. The cut-sprouts were selected on the basis of their stem length i.e. 20—25cm for Koganesengan and 15—20cm for Kokei No.14 and on the basis of their fresh weight i.e. 20—32g for Koganesengan and 12—24g for Kokei No.14.

2. *Holding procedures*

In both experiments the cut-sprouts were stored for 0, 5, 10, 15 days before transplanting and several measurements were performed. The cut-sprouts were stored in a semiunderground storeroom for seed tubers at the National Agriculture Research Center. The conditions in the storeroom during the holding period were 18.0 ± 0.5°C, 90 ± 0.5% relative humidity (RH) in 1983 and 14.5 ± 0.5°C, 95 ± 1%RH in 1985, and illumination with weak fluorescent lamps ($0.3\mu E \cdot m^{-2} \cdot s^{-1}$).

3. *Measurements during the holding period*

In both experiments changes in the fresh weight, number of fallen leaves and number of roots from basal 3 nodes were measured every 5 days during the holding period in all the cut-sprouts. In both experiments a cut-sprout with 7 nodes was cut into 2 parts including basal 3 nodes and upper 4 nodes, and 6 cut-sprouts were used for the following measurements : dry weight of leaf blades, petioles and stems in each part. In 1985 another set of

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10 cut-sprouts was also used for the additional determination of the dry weight ratio in the same way.

4. *Rooting experiments*

In 1983 6 cut-sprouts and in 1985 9 cut-sprouts of each cultivar were transplanted into 1/5000a Wagner pots with 3kg clay soil and without fertilizer every 5 days during the holding period. Basal 3 nodes of the cut-sprouts were inserted into the soil vertically. Three cut-sprouts were transplanted in a pot with 2(1983) and 3(1985) replications, placed in a growth cabinet where the conditions were 28°/20°C, 70%RH, 12h day length and 330μE•m^{-2} • s^{-1} light intensity at the plant surface. The period of exposure to high temperature was synchronized with the photoperiod. The soil moisture was checked by means of pot weight and kept at about 70% of the field capacity.

One week after transplanting the soil was washed away and the number and length of the adventitious roots more than 1mm in length as well as the dry weight of the roots were measured. The number of leaves which fell or did not fall was also counted. The thickest parts (about 5mm in length) of 15 roots, which were the thickest ones sampled, per treatment were fixed by FAA. These were prepared by using an Acrytron E embedding kit (Mitsubishi-Rayon Inc.) according to the method of SENOO et al.[10], and transverse sections 10μm thick were made. To determine the developmental stage according to TOGARI[11], WILSON and LOWE[13], the sections were stained by safranine and fast green FCF and examined under a microscope.

Results

The measurements of cut-sprouts during the holding period are shown in Fig.1.

Fresh weight decreased appreciably with the duration of the holding period and on the 15th day of holding the weight decreased by about 60% of the initial value in both cultivars and years (Fig.1-A). Conversely the dry weight percentages of the cut-sprouts increased gradually with the duration of the holding period (Fig.1-B). Leaves at the lower nodes began to wither 10 days after cutting, and after 15 days the number of fallen leaves increased i.e. about 2 and 3 leaves in 1983 and 1985, respectively (Fig.1-C). In 1983 roots started to appear after 5 days of holding and their number increased rapidly from the 5th to the 10th day of holding, but after 10 days of holding there was no increase in the number of roots. In 1985 on the other hand only few roots appeared until the 10th day of holding and thereafter the number of roots increased by as much as 2 in both cultivars (Fig.1-D).

Number of roots, average root length, total length of roots, dry weight of roots and number of living leaves at 1 week after transplanting are shown in Fig.2.

The number of roots decreased significantly at 5% in the cut-sprouts stored for 5 to 15 days and the minimum values were observed on the 10th day of holding (Fig.2-A), whereas the average root length increased significantly at 1% and the maximum values were observed on the 10th day of holding (Fig.2-B). Thus the total length of the roots increased significantly at 1% in the stored cut-sprouts in spite of the decrease in the number of roots (Fig.2-C). A marked increase in the dry weight of the roots was also observed when the holding period lasted 5 days. But during the subsequent holding periods the dry weight decreased again, indicating that the dry weight of the roots of the cut-sprouts stored

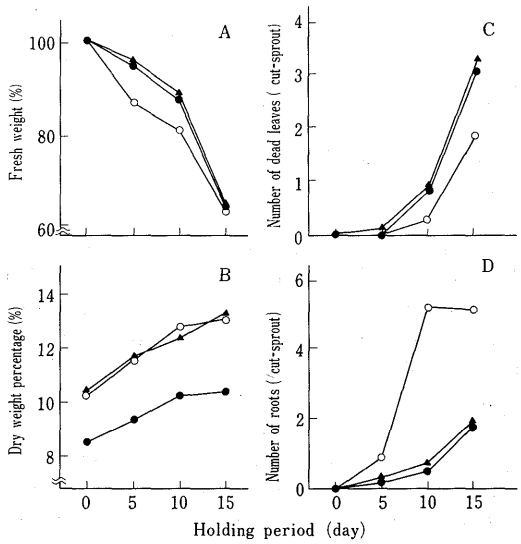

Fig. 1. Changes in fresh weight (A), dry weight percentage (B), number of fallen leaves (C) and number of roots at basal 3 nodes (D) of cut-sprouts during the holding period.
○; Koganesengan (1983). ●; Koganesengan (1985). ▲; Kokei No.14 (1985).

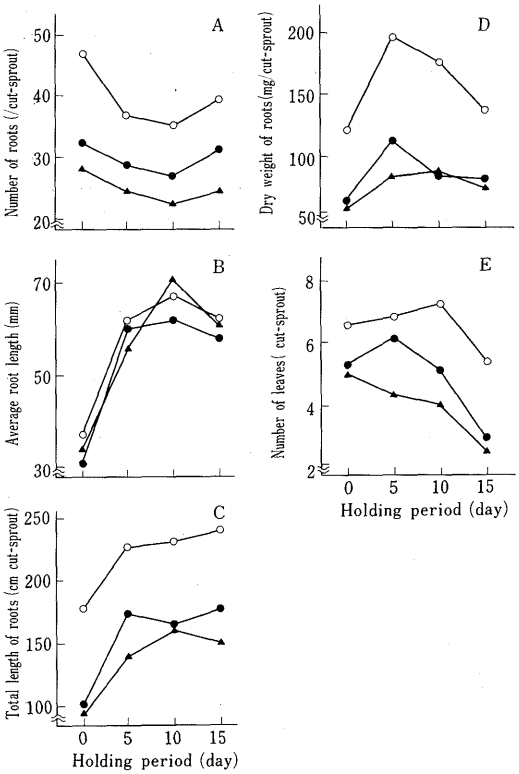

Fig. 2. Effect of holding period on the number of roots (A), average root length (B), total length of roots (C), dry weight of roots (D) and number of living leaves (E) at 1 week after transplanting.
Symbols are the same as those of Fig.1.

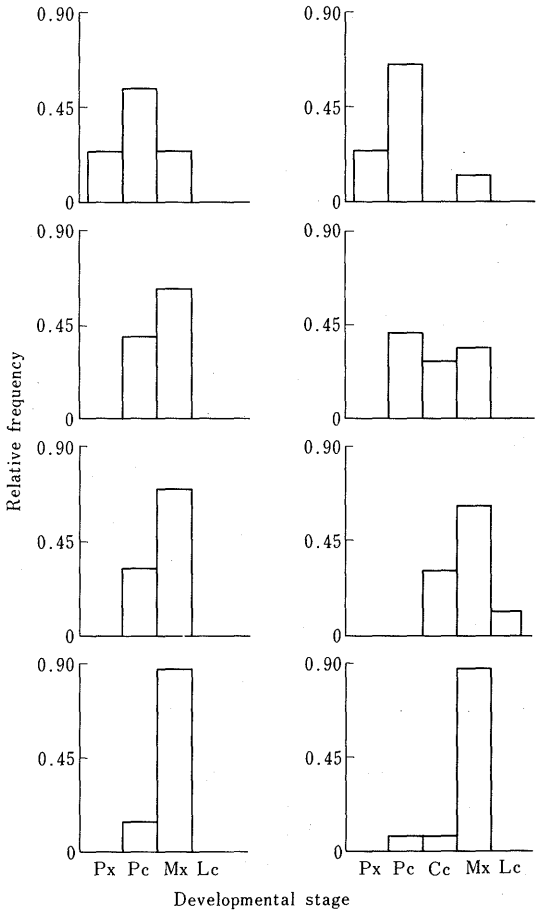

Fig. 3. Effect of holding period for 0 (upper), 5 (second column), 10 (third column) and 15 (lower) days on the variations in the developmental stages of roots in Koganesengan (left) and Kokei No.14 (right) at 1 week after transplanting in 1985.
Px ; Proto xylem differentiation stage.
Pc ; Primary cambium differentiation stage.
Cc ; Central cell differentiation stage.
Mx ; Meta xylem differentiation stage.
Lc ; Lateral cambium differentiation stage.

for 15 days was the lowest in comparison with those stored for 5 and 10 days (Fig.2-D). Varietal differences were observed in the withering characteristics of the basal leaves during the holding period. In Koganesengan the number of leaves at 1 week after transplanting was the same as that in the initial stage until the 10th day of holding in both years. In Kokei No.14 the number of leaves decreased gradually with the duration of the holding period. In both cultivars, the transplants stored for 15 days bore 2 and 3 leaves less than those which had not been stored in 1983 and 1985, respectively (Fig. 2-E).

Variations in the developmental stages of the thickest roots that were observed in 15 samples at 1 week after transplanting in 1985 are shown in Fig.3. Because the typical central cell in Koganesengan was observed in few roots even in the stage of meta-xylem differentiation except in the materials stored for 15 days as shown in Fig.3, the presence of the cell was inculded in the meta-xylem differentiation stage. In both cultivars the number of roots in the meta-xylem differentiation stage increased gradually with duration of the holding period.

The results of anatomical observations of the same roots as those indicated in Fig.3 are shown in Table 1.

Although in Koganesengan the root diameter did not differ significantly among the

Table 1. Anatomical characteristics of the thickest 15 roots at 1 week after transplanting.

Cultivar	Holding period (days)	Root diameter (mm)	Stele diameter (mm)	Number of cell layers in primary cambium	Number of lignified cells in stele (A)	Number of parenchyma cells in stele (B)	Lignification ratio (A/A+B) (%)
Kogane-sengan	0	1.16	0.32b	2.5b	83.1b	465.6b	15.1b
	5	1.23	0.46a	3.7a	109.7a	615.7a	15.1b
	10	1.15	0.39ab	3.6a	107.3a	589.3a	15.4b
	15	1.10	0.38ab	3.5a	103.2a	510.4ab	16.8a
Kokei No.14	0	1.21a	0.31b	2.2b	57.8c	488.4b	10.6b
	2	1.21a	0.37ab	3.2a	77.1bc	616.1a	11.1b
	10	1.26a	0.42a	3.5a	121.4a	611.1ab	16.6a
	15	1.11b	0.33b	3.0a	103.8ab	478.0b	17.8a

Note; Means within a column followed by the same letter did not differ at 5% level of significance according to Duncan's Multiple Range Test.

holding periods, in Kokei No.14 it was smaller in the materials stored for 15 days than in those stored for 5 and 10 days and for those which had not been stored. The stele diameter was the smallest in the roots of cut-sprouts which had not been stored (0 day) in both cultivars, and it attained the highest value when cut-sprouts were stored for 5 days in Koganesengan and for 10 days in Kokei No. 14. In both cultivars no difference was found in the number of cell layers in the primary cambium among the different holding periods, but the number was the smallest in the roots of the cut-sprouts which had not been stored. The number of lignified cells in the stele in each holding period showed the following order: $5>10>15>0$ days in Koganesengan and $10>15>5>0$ days in Kokei No.14, and that of the parenchyma cells in the stele: $5>10>15>0$ days in Koganesengan and $10>5>0>15$ days in Kokei No.14. The lignification ratio of the stele, which indicated the number of lignified cells to the total number of cells in steles was significantly higher in the roots of cut-sprouts stored for 15 days than in the roots of the materials stored for 0, 5 and 10 days in Koganesengan, while it increased with the duration of the holding period, being significantly lower after 0 and 5 days of holding than after 10 and 15 days in Kokei No.14.

Discussion

The number of roots appearing in the cut-sprouts at 1 week after transplanting decreased after holding for 5 to 15 days. Root elongation, howerer, was accelerated and the total lenght which is the product of the root number and average root length increased by the holding (Fig.2). There are few reports on the effects of the holding of cut-sprouts on the rooting of sweet potato. KAMATANI[6] reported that the number of roots and maximum root length did not change until 6 days after holding at 19°C in a dark room (the value of the relative humidity was not recorded). In the present study holding was carried out at 14.5 or 18°C and a high relative humidity and these conditions were very stable during the holding period. The discrepancy between the results may be due to the holding conditions.

In cut-sprouts of sweet potato the root primordia are already developed at the leaf gap when they are cut[11]. Thus it is assumed that the main effects of holing are to prevent the formation of new root primordia after transplanting and accumulate the nutrient reserves for the elongation of the root primordia already formed.

Since the establishment of cut-sprouts is considered to be closely related to the total root length[9], it is likely that the establishment can be accelerated by holding. Moreover it is considered that the lesser the number of roots and the longer the roots the more rapidly the roots are able to reach the deep and moist soil layers in comparison with a large number of roots and shorter roots when the same amount of reserves is consumed. Consequently it may be considered that holding is beneficial in accelerating the establishment of cut-sprouts in the field.

Anatomical observation showed that 5 or 10 days of holding accelerated the root developmental stage, and activated the primary cambium without resulting in the lignification of

the stele (Fig.3 and Table 1). Since these facts are closely related with the fast development of tuberous roots[2,11,13], holding may also have a favorable effect on this aspect.

HALL[3], HAMMETT[4] and HAMMETT[5] reported the beneficial effect of holding on the yield increase of sweet potato. This may be ascribed to the above-mentioned advantageous effects of holding. In the present study, withering of the basal leaves of cut-prouts was remarkable on the 15th day of holding (Fig. 1). As the leaves of cut-sprouts play an important role in rooting [1,2,7] along with being the major source of nutrients for the rooting[8], excess defoliation is unfavorable. Thus the decrease in the root dry weight on the 15th day of holding may be attributed to the shortage of nutrients due to the fall of the lower leaves. Moreover, the anatomical observation showed that a holding period of 15 days accelerated the lignification of the stele, which was closely related to the suppression of tuberous root development[2,11]. Based on these results the duration of the holding period should not exceed 10 days although the conditions during the holding period should be further clarified.

From the facts discussed previously, it can be concluded that the holding of cut-sprouts for a period of 5-10 days is effective in promoting the rapid establishment of cut-sprouts after transplanting.

Summary

Effects of holding of cut-sprouts on rooting in sweet potato were investigated in using the cvs. Koganesengan and Kokei No.14. Cut-sprouts were stored for 0, 5, 10, 15 days at 18°C, 90%RH or 14.5°C, 95%RH with fluorescent lighting. Rooting experiments in pot culture were conducted in a controlled environment. The results obtained are as follows:

1. The fresh weight of the cut-sprouts decreased gradually with the duration of the holding period, whereas the dry weight ratio increased. The lower leaves of the cut-sprouts began to wither after 10 days of holding and at 15 days, 2—3 basal leaves fell. Remarkable rooting was observed for a period of holding ranging from 10 to 15 days (Fig. 1).

2. The number of roots at 1 week after transplanting decreased in the cut-sprouts stored. Individual roots, however, were longer in the stored cut-sprouts than in those which had not been stored. Consequently the total length of the roots increased by holding. Although the dry weight of the roots was also increased after a 5 day period of holding, subsequently the dry weight decreased, particularly in the materials stored for 15 days. The number of living leaves also decreased markedly in these materials (Fig. 2).

3. The anatomical observation of the thickest roots showed that the developmental stage of the roots was accelerated by holding (Fig. 3). The primary cambium of the roots was activated by holding. Howerer the lignification of the stele in the roots was accelerated by the holding for 15 days (Table 1).

Based on the results obtained it can be concluded that the holding of cut-sprouts for 5—10 days promotes the rapid establishment of cut-sprouts and accelerates the development of tuberous roots in sweet potato.

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** In Japanese.

〔和 文 摘 要〕

サツマイモ苗の取り置きに関する研究

第1報 苗の発根に及ぼす取り置きの影響

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サツマイモ苗の取り置きが苗の発根に及ぼす影響をコガネセンガンと高系14号について2年間調査した．苗の取り置きは1983年は18°C，90% RH，1985年は14.5°C，95% RH，それぞれ弱光下で，0，5，10，15日間行った．発根実験は，土耕により，28/20°Cの制御環境下で行った．

得られた結果は次のとおりである．

1. 取り置き期間が延びるにしたがい苗の生重は減少し，苗の乾物率は増加した．苗の下位葉は10日目から枯死し始め，15日目にはその2〜3葉が枯死した．取り置き中に苗の発根が見られ，1983年は10日目，1985年は15日目に最大に達した（第1図）．

2. 取り置き処理により挿苗1週間後の苗当たり根数は減少した．逆に根の伸長は取り置き処理により促進され，平均根長が増加した．このため総根長も取り置き処理により増加した．根の乾物重も取り置き処理で増加したが，15日取り置くと減少する傾向が認められた．挿苗1週間後の展開葉数は15日取り置き区で最も少なかった（第2図）．

3. 各区の最太根15本の組織学的観察によると，根の発育ステージは取り置きしたものの方が進んでいた（第3図）．また，1次形成層の活性も取り置き区で高かった．中心柱の木化は15日取り置き区で進んでいた（第1表）．

以上の結果から，サツマイモ苗の5—10日間取り置きは，苗の活着及び塊根分化を促進することが示唆された．