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Dry Matter Production of Sweet Potato in True Seed Planting Culture*

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Abstract : To clarify the reason of lower yield in true seed planting (TSP) culture than that of ordinary transplanting culture of stem cuttings, the top and storage root growth were investigated among six populations in TSP culture and two cultivars in ordinary culture.

There was a large variance in the yield among the TSP populations which differed in parental clones. Especially, one of the TSP populations showed a high yield similar to the high yielding cultivar.The difference in the dry matter production among the materials during the period from late August to middle October, which was major cause of the yield difference, was mainly affected from the difference in the leaf efficiency (total dry weight increase/mean leaf dry weight). Since its leaf efficiency tended to be higher in the materials with the higher storage root weight ratio (storage root dry weight/total dry weight) in the late August, a close correlation was observed between the storage root weight ratio in the late August and the yield among the materials.

The present results indicated that, with the aid of some cultural practices used to improve early top growth in the TSP culture, we could expect as high a yield in the TSP culture as in the ordinary culture, by using an excellent TSP population. It was also suggested that there was a large difference in storage root sink potential among the TSP populations, and it mainly governed the leaf efficiency and dry matter production during later storage root bulking period and thus the yield.
Key words : Cultivation method, Dry matter production, *Ipomoea batatas* Lam., Leaf efficiency, Sink potential, Sweet potato, True seed.

種子播き栽培カンショの乾物生産：岩間和人・吉永　優**・久木村　久**（三重大学教育学部・**九州農業試験場）

要　旨：カンショの挿苗栽培に比較して種子まき栽培では低収である理由を明らかにするために，交配親を異にする種子播き6集団と挿苗2品種における地上部と塊根の生長を調査した．

種子播き集団間では収量が大きく異なり，種子播き集団の一つは多収の挿苗品種に類似した収量を示した．供試材料間の収量の差異は8月下旬から10月中旬の期間の乾物生産量の差異に主として起因し，これは葉の効率，すなわち全乾物重の増加量/平均葉乾物重の差異の影響を強く受けた．さらに，葉の効率は8月下旬における塊根重歩合（塊根乾物重/全乾物重）の高い供試材料で高い傾向を示したことから，8月下旬の塊根重歩合と収量との間に密接な相関関係が認められた．

以上の結果から，種子播き栽培の初期生長の促進を図る栽培法を用いた場合，優れた種子播き集団では多収の挿苗品種に類似した収量が得られるものと推察した．さらに，種子播き集団間では塊根のシンク能力に大きな差異があり，これが塊根肥大後期の葉の効率ならびに乾物生産，さらには収量を主として規制していることが示唆された．

キーワード：カンショ，乾物生産，耕種法，シンク能力，真正種子，葉の効率．

The true seed planting (TSP) culture of sweet potato is expected to simplify the planting process compared with the ordinary culture by transplanting of stem cuttings[2,12]. It was estimated that the TSP culture could decrease the working hours during the growing season to less than 40% of the ordinary culture[12]. Several experiments[2,10,11,13,14] and breeding works[12,15] to establish the TSP culture have been reported since the findings of natural flowering clones under the field conditions of Japan by Shigemura et al.[9]. In these experiments, however, it was found that the yield in the TSP culture was low, approximately 70% at maximum as compared with that of the high yielding cultivar, Koganesengan, in the ordinary culture.

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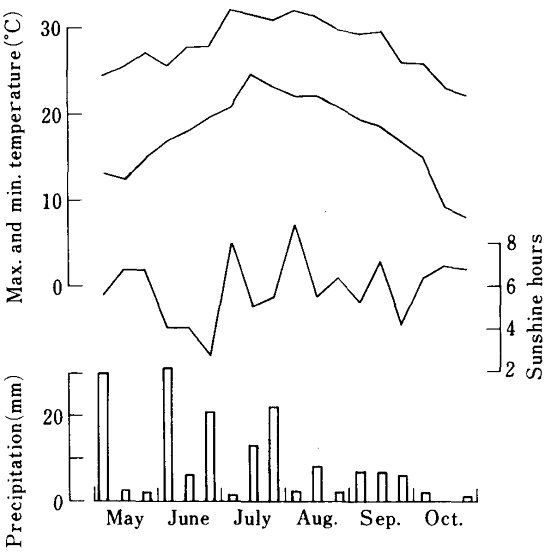

Fig. 1. The changes in daily maximum and minimum temperature, sunshine hours and precipitation during the growing season.

Yamakawa and Sakamoto[11,12,13,14] claimed that major reason for the low yielding ability in the TSP culture was the slow top growth during the early growing season. In our preliminary experiment[6] the plants in the TSP culture showed the lower ratio of the storage root dry weight to the total dry weight during the storage root bulking period and resulted in the lower yield than Koganesengan. However, one of the cultivars examined (Tsurusengan, a cultivar for animal feeding of the tops) showed similar values in these characters with the TSP plants. It was suggested from the results that the low yield in the TSP culture was due to not only the culture method but also the genetical potential of the materials used.

The purpose of the present experiment was to clarify the difference in the top and storage root growth among several populations in the TSP culture comparing with those of main cultivars in the ordinary culture. The TSP populations were planted earlier and at the higher density than the cultivars, and all the plots were mulched before planting, in order to lower the effect of delay of early top growth on later plant growth and yield in the TSP culture[10,13].

Materials and Methods

The experiment was carried out at the Kyushu National Agricultural Experiment Station (Kumamoto, 33°N) in 1988. The soil is Humas-rich Andosoil. As shown in Table 1, six TSP populations and two cultivars were used. The TSP populations except for KA-85-MP were the offsprings of polycrossings with several parental clones by natural pollination. KA-85-MP was the mixed offspring from three single crossings of Kanto No. 85 with Kyukei 7413-10, 7416-10 and 7509-4, which were breeding clones for the ordinary culture, by artificial pollination.

The TSP populations were directly sown on May 10 at distance between hills of 71cm × 15cm (9.39 hills/m^2) with 2 seeds per hill. The cultivars were planted on June 8 at distance between hills of 71cm × 30cm (4.70 hills/m^2) with one stem cutting per hill. Each stem cutting was approximately 15 gram in fresh weight, 25cm in length having 5 stem nodes. Mulching by polyethylene film was done before planting. A compound fertilizer with 1.8, 6.0, 6.0 g/m^2 for N, P_2O_5, K_2O, respectively, was applied in the autumn of the preceding year for the wheat, which was incorporated in the spring of the experimental year. The fertilizer of the same rates was also applied before planting. A randomized block design with two replications was employed. Each plot consisted of 4 rows of 3m length. Pesticides were sprayed on July 27 and August 19 to prevent the leaf damage from *Aedia leucomelas* L..

Samplings were done on August 23-25 (the approximately maximum stage of the top weight) and on October 17-19 (the harvesting stage). Thirty hills for each TSP population and 15 hills for each cultivar were harvested at each sampling time. Although the stems and leaves of each hill were combined in a complicated way with those of neighboring hills, they were carefully separated and cut off at the ground surface. Dead leaves and stems, were not collected. Each hill was dug up to a depth of about 30 cm to obtain the roots. The dry weights of leaves, stems, roots thicker than 5 mm in diameter (storage roots) and thinner roots (fiberous roots) were determined after oven-drying for 48 hrs at 80°C. At the harvesting stage, the number and fresh weight of storage roots were also recorded. Since one to three hills had no storage root in the TSP populations with the exception of KA-85-MP and KNF-75A, these hills were omitted from

Table 1. The total dry weight and dry weight of each organ in the late August.

Materials	Dry weight (g/m^2)				
	Total	leaf	Stem	Storage root	Fibrous root
TSP culture	1) 2)				
DJ-8 (1975)	554.7 * ns	135.9 ns ns	357.9 ns ns	47.0 ** **	13.8 ns *
860P23	567.8 * ns	111.5 ns ns	381.0 ns **	60.5 ** **	14.8 ns **
KNF-75A	727.9 nsns	169.6 ns ns	344.9 ns *	198.2 ns ns	15.2 ns ns
NGS-85	539.5 * ns	99.0 * ns	316.2 ns *	114.0 ** **	10.3 ns ns
KNF-73C	614.2 nsns	128.8 ns ns	321.5 ns **	152.4 ** **	11.5 ns ns
KA-85-MP	814.3 —**	156.7 — *	340.0 — **	306.5 — ns	11.1 — ns
Ordinary culture					
Norin 2	375.7 ****	72.3 ** **	136.8 ** *	161.2 ** **	5.5 ** **
Koganesengan	564.4 **—	114.7 * —	190.3 ** —	249.7 ns —	9.7 ns —

*, ** and ns indicate a signficance at 5 and 1% level and nonsignificance, respectively, at t Test with 1) KA-85-MP and 2) Koganesengan.

Table 2. The weight ratio of each organ to total dry weigth in the late August.

Materials	Weight ratio (%)			
	leaf	Stem	Storage root	Fibrous root
TSP culture	1) 2)			
DJ-8 (1975)	23.4 ** *	66.5 ** **	6.7 ** **	3.4 ** **
860P23	20.1 ns ns	66.9 ** **	9.8 ** **	3.3 ** **
KNF-75A	22.3 * ns	46.2 ns **	28.4 * **	3.2 ** *
NGS-85	18.4 ns ns	56.8 ** **	22.2 ** **	2.5 * ns
KNF-73C	21.0 ns ns	49.7 * **	27.2 * **	2.1 ns ns
KA-85-MP	18.6 — ns	39.8 — *	40.1 — ns	1.5 — ns
Ordinary culture				
Norin 2	19.5 ns ns	37.2 ns ns	41.8 ns ns	1.6 ns ns
Koganesengan	20.5 ns —	33.8 * —	44.0 ns —	1.8 ns —

*, ** and ns indicate a signficance at 5 and 1% level and nonsignificance, respectively, at t Test with 1) KA-85-MP and 2) Koganesengan.

the calculations of one fresh weight and dry matter percentage of storage roots. The meteorological data during the growing season observed at the experimental station was shown in Fig. 1.

Results

The total dry weight (DW), DW of each organ and ratio of each organ's DW to total DW (weight ratio) in the late August were shown in Table 1 and 2. The total DW tended to be larger in the materials with larger leaf DW ($r=0.911^{**}$). The leaf DW ratios in all materials were almost similar, approximately 20%. The results indicated that during the growth until this stage the amount of leaf growth mainly governed the total plant growth. In addition, comparing the total DW and leaf DW between the TSP populations and the cultivars, the TSP population tended to be larger in these characters. It indicates that the cultural practice such as the denser and earlier planting in the TSP populations and mulching improved the early top growth.

Table 1 also shows that there was a large difference in the storage root DW among the materials. Although the storage root DW tended to be larger in the materials with the larger total DW ($r=0.535$), the difference in the storage root DW among the materials was relatively larger than that of the total DW ; i.e. the ratio of maximum value to minimum value

Table 3. The total dry weight increase, mean leaf dry weight and total dry weight increase per unit mean leaf dry weight (leaf efficiency) during the period from late August to middle October.

Materials	Total DW increase (g/m^2)	Mean leaf DW (g/m^2)	Leaf efficiency (g/g)
TSP culture			
DJ-8 (1975)	−9.7	102.9	−0.1
860P23	207.5	99.5	2.1
KNF-75A	474.8	148.7	3.2
NGS-85	503.1	84.8	5.9
KNF-73C	566.1	106.5	5.3
KA-85-MP	699.8	149.8	4.7
Ordinary culture			
Norin 2	464.5	61.7	7.5
Koganesengan	538.8	91.4	5.9

was 6.5 in the storage root DW, while 2.2 in the total DW. It means that the storage root weight ratio differed among the materials. Actually, its value ranged from 6.7%to 44.0%. Since the leaf weight ratio was almost similar among the materials, the stem weight ratio also showed a large difference according to the difference in the storage root weight ratio. These two characters showed a highly significant negative correlation (r=−0.991**). These results indicate that during the growth until this stage there was a large difference in the dry matter distribution between the storage root and the stem among the materials, and its difference gave rise to the differences in the storage root and stem weight ratios at this stage. In addition, comparing these characters between the TSP populations and the cultivars, the cultivars tended to have higher storage root weight ratio and lower stem weight ratio than the TSP populations. However, it may be noted that one of the TSP populations, KA-85-MP, showed similar value to the cultivars.

During the growth thereafter to the harvesting stage, as shown in Table 3, the total DW increase showed a large difference among the materials, −9.7 g/m^2 in minimum and 699.8 g/m^2 in maximum. Considering the relations of the total DW increase with the mean leaf DW and the total DW increase per unit mean

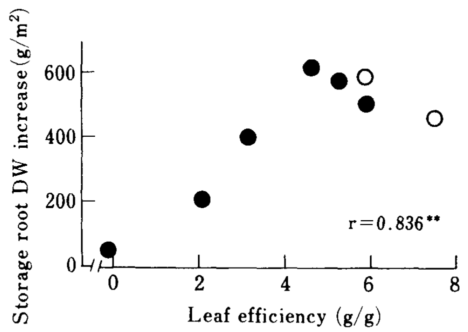

Fig. 2. The relationship between the dry weight increase of storage root and the leaf efficiency during the period from late August to middle October.
● : TSP population, ○ : Cultivar.

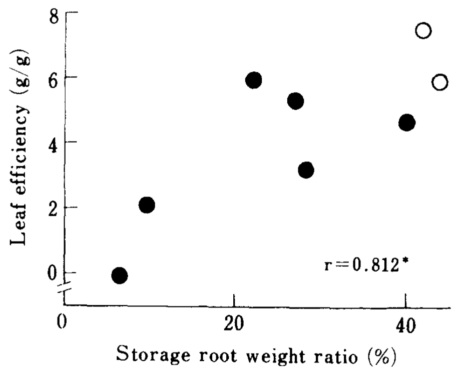

Fig. 3. The relationship between the storage root weight ratio in the late August and the leaf efficiency during the period from late August to middle October.
● : TSP population, ○ : Cultivar.

leaf DW (leaf efficiency), a simple correlation coefficient of the total DW with the leaf efficiency and the mean leaf DW was 0.836* and 0.250, respectively. The difference in the leaf efficiency among the materials was much larger than that in the mean leaf DW. Therefore, it was indicated that the difference in the total DW increase during this period was mainly affected from the difference in the leaf efficiency among the materials. The dry matter produced during this period was mainly distributed to the storage roots in all materials. The distribution ratio of the dry matter to the storage roots ranged from 85% to 100% among the materials (one material which showed the decrease of the total DW was omitted from the calculation and the values more than 100% were considered as 100%). As a result, a simple correlation coefficient of

Table 4. The fresh and dry matter yield, dry matter percentage, number and one weight of storage root in the middle October.

Materials	Fresh yield (g/m²)	Dry matter yeild (g/m²)	Dry matter percentage	Number (/m²)	One fresh weight (g)
TSP culture	1) 2)				
DJ-8 (1975)	348 ** **	101.6 ** **	27.7 ** **	15.7 ns **	21.8 ** **
860P23	871 ** **	268.8 ** **	30.9 ** **	19.1 ns **	49.7 ** **
KNF-75A	1877 ns ns	600.1 * ns	32.3 * *	13.5 ns **	150.2 ns **
NGS-85	2081 ns ns	622.5 ns ns	28.9 ** **	18.2 ns **	114.7 * ns
KNF-73C	2439 ns ns	733.7 ns ns	30.6 ** **	13.8 ns **	197.9 ns **
KA-85-MP	2768 — ns	927.9 — ns	33.8 — ns	18.5 — **	181.7 — **
Ordinary culture					
Norin 2	1955 * ns	626.9 * *	32.1 ** **	23.8 ns ns	87.0 ** ns
Koganesengan	2491 ns —	841.1 ns —	33.8 ns —	30.4 ** —	84.6 ** —

*, ** and ns indicate a signficance at 5 and 1% level and nonsignificance, respectively, at t Test with 1) KA-85-MP and 2) Koganesengan.

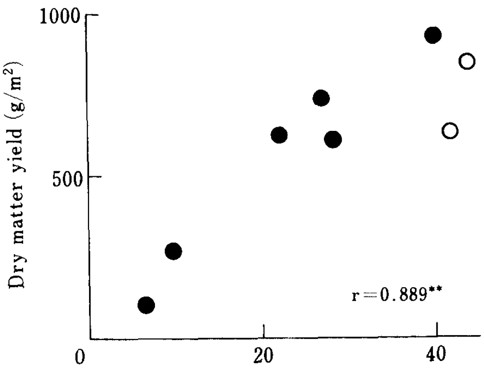

Fig. 4. The relationship between the storage root weight ratio in the late August and the yield.
●: TSP population, ○: Cultivar.

the storage root DW increase with the total DW increase was highly significant (r=0.977**). As shown in Fig. 2, therefore, a significant positive relationship was observed between the storage root DW increase and the leaf efficiency among the materials.

The above mentioned results indicated that during the later storage root bulking period the difference in the leaf efficiency among the materials was the main factor affecting the difference in the dry matter production and thus the storage root DW increase. Considering its relation with the difference in the storage root weight ratio found in the late August, the materials with the higher storage root weight ratio tended to have the higher leaf efficiency (Fig. 3). Correspondingly, a significant positive correlation was also observed between the storage root weight ratio and the storage root DW increase (r=0.842**).

Table 4 listed up the yield characters in the middle October. Two TSP populations, DJ-8 and 860P23, showed significantly smaller values in the fresh yield than the cultivars, while the values of the other TSP populations were similar to or larger than those of the cultivars. Especially, KA-85-MP of the TSP population showed 42% and 11% higher fresh yield than Norin No. 2 and Koganesengan of the cultivars, respectively. Although the difference in the dry matter percentage of storage root among the materials was significant, it was much smaller than the difference in the fresh yield. Therefore, the tendency of the difference in the dry matter yield among the materials was similar to that of the fresh yield.

Considering the relation of the dry matter yield with the storage root growth, about 70% of the dry matter yield was resulted from the increase of storage root DW during the period from late August to the harvesting in all the materials. The difference in the dry matter yield among the materials depended mainly on the difference in the storage root DW increase during this period. A highly significant correlation between these two factors was observed (r=0.982**). Therefore, corresponding to the results mentioned in Fig. 3, the dry matter yield also showed a significant positive correlation with the storage root weight ratio in the late August (Fig. 4) ; i.e. the dry matter yield tended to be higher in the materials with the higher storage root weight ratio in the late August.

Discussion

The present experiment clarified that there was a large variance in the yield among the TSP populations which differed in parental clones. Especially, KA-85-MP showed the high yield similar to Koganesengan of the high yielding cultivar under the cultural conditions of the present study. The results indicate that, with the aid of some cultural practices, i.e. denser and earlier planting and mulching in order to improve the early top growth of the TSP culture, we can expect a high yield in the TSP culture the same as in the ordinary culture, employing an excellent TSP population.

The present results also indicated that the difference in the dry matter production among the materials during the period from late August to middle October, which was the major cause of the yield difference, was mainly affected from the difference in the leaf efficiency. Since its leaf efficiency tended to be higher in the materials with the higher storage root weight ratio in the late August, the close correlation was observed between the storage root weight ratio in the late August and the yield. It was, therefore, considered that the highest yield of KA-85-MP among the TSP populations and higher yield of the cultivars compared with the TSP populations were mainly due to their characteristics of higher storage root weight ratio.

In the ordinary culture it is well recognized that there is a large variance in the storage root sink potential (the potential for the storage roots to become large) among the cultivars and breeding clones[4,5,7,8]. The plants with higher storage root sink potential show higher distribution ratio of the dry matter to the storage roots[4,5], higher dry matter production through higher photosynthetic activity[3,7,8], and result in higher yield[1]. Since the storage root weight ratio mentioned in the present study represents the aggregation of the distribution ratio of the dry matter to the storage roots during the preceding period, we hypothesize that there is a large variance in the storage root sink potential among TSP populations as cultivars and clones in the ordinary culture, and it mainly governs the leaf efficiency and dry matter production during the later storage root bulking period and thus the yield. We must use a material which has a high storage root sink potential in order to get a high yield in the TSP culture the same as in the ordinary culture.

Although KA-85-MP showed the highest storage root weight ratio and yield among the TSP populations examined, it did not have the characteristic for natural flowering under the field condition. Its true seed production must be made by artificial pollination. It means that KA-85-MP cannot practically be used for the TSP culture due to the seed cost. However, in order to breed a high yielding TSP population, the present results are very meaningful. Since KA-85-MP was produced from the crossing between the clones to breed a high yielding cultivar in the ordinary culture, it was suggested that the genes associated with high storage root sink potential and yield in the TSP culture were the same as those in the ordinary culture and have been accumulated to breeding clones and cultivars in the ordinary culture during the long term breeding practices up to the present. Yamakawa and Sakamoto[15] reported that the plants with higher yield in the TSP culture also showed higher yield in the ordinary culture of the next year. Their result well supports our expectation.

In the breeding for the TSP culture previously conducted, however, the parental clones to produce the TSP populations were selected from the clones having the characteristic of natural flowering[12,15]. Most of the breeding clones and cultivars for the ordinary culture have not been used in the TSP breeding. Shigemura et al.[9] reported that the characteristic of natural flowering was introduced from one original clone and the improvement in flower producing ability was rapidly achieved. Therefore, it is expected that crossings of cultivars and breeding clones for the ordinary culture having high storage root sink potential and yield with clones having a characteristic of natural flowering can effectively produce parental clones to breed TSP populations with high storage root sink potential and yield.

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