Utilization of K_2O/N Ratio as Selection Character in Tuber Yield of Sweet Potato

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Studies were carried out to identify a new index for the selection of tuber yield in sweet potato breeding. The K_2O/N ratio in tubers showed a positive correlation with fresh and dry tuber yield, and a negative correlation with nitrogen content in tubers. Nitrogen content in tubers showed a negative correlation with tuber and starch yield. Dry matter and starch content in tubers showed a negative correlation with the K_2O content in tubers. Estimate of "heritability in the broad sense" of dry matter content, K_2O and nitrogen content and K_2O/N ratio averaged 89.2, 68.8, 65.9 and 63.3 percent, respectively, in a population of 267 first year clones selected from 711 clones of seedlings derived from polycross seeds. These characters in the 1st year clones were closely related to those of the second year clones. Phenotypic variance in these characters was based on genetic variance. In the seedlings from polycross seeds, the clones selected according to a high K_2O/N ratio and low nitrogen content induced high tuber yield in the 2nd year clones. It is concluded that the K_2O/N ratio and nitrogen content in tubers could be a useful selection index for tuber yield in sweet potato breeding.

KEY WORDS : Sweet potato, K_2O/N ratio, selection, tuber yield, breeding.

Introduction

In sweet potato breeding in Japan, it is often difficult to observe a significant correlation between the tuber yield of a clone in the seedling establishment year (abbreviated to "1st year clone") and of the clone cultivated in the 2nd year after seedling establishment (abbreviated to "2nd year clone"). It is difficult to estimate accurately tuber yield of sweet potatoes in a yield trial of the 1st and 2nd year clones with one or several plants, due to the competition in vine growth among neighboring clones in sweet potatoes. In general, tuber yields are evaluated in a trial after the 3rd year of seedling establishment. It was thus found necessary to identify a new index for the selection of tuber yield in sweet potato breeding.

TSUNO and FUJISE (1965) reported that low nitrogen content and high K_2O/N ratio in fresh tubers correlated well with tuber yield in sweet potatoes. However the data were obtained in a limited number of varieties. This paper deals with 1); the relationships between tuber yield and tuber characters in several sweet potato varieties, namely nitrogen and K_2O content in fresh or dry tubers, K_2O/N ratio, and dry matter content in tubers, 2); the "heritability in the broad sense" of the tuber characters of the 1st year clone population derived from polycross seeds, 3); the effect of selection by using the K_2O/N ratio for the tuber yield of the 1st year clones.

Materials and Methods

(1) 1981 trial

Thirty four varieties (A trial) and 24 varieties (B trial) were grown in fields of the

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Sweet Potato Breeding Station, National Agriculture Research Center, Yotsukaido, Chiba, Japan. These sweet potato varieties consisted of typical local varieties and registered leading varieties. Twelve plants per clone in the A trial and 24 plants in the B trial were grown, respectively. Fresh and dry tuber yield, dry matter, K_2O and nitrogen content and K_2O/N ratio in tubers were measured. Dry matter content of tuber was deduced from the dry weight of 100 g of slit fresh tubers after drying at 105°C for 6 hours in an electric oven. Potassium was extracted with 100 ml of 4 N of ammonium acetate solution at pH 7.0 from 500 mg of dry tuber powder. Potassium content was compared with K_2O standard solution by flame spectrophotometry. Nitrogen content in 500 mg dry tuber powder was analysed using the C-N coder MT 500, Yanagimoto Co.

(2) 1982 trial

Thirty nine typical sweet potato varieties were grown and 24 plants per variety were planted and harvested. Fresh and dry tuber yield, starch yield, dry matter, starch, potassium and nitrogen content, and K_2O/N ratio in tubers was measured. Dry matter and potassium content in tubers was evaluated by the procedures already described. Starch content was measured by weighing dry starch in 200 g slit fresh tubers which were broken up by an electric mixer at 9500 rpm for 90 seconds with 500 ml water. Starch was filtrated in a 200 mesh sieve and 5 liter pressure tap water. Starch in the filtrate was precipitated overnight and the supernatant was discarded. Starch was weighed after drying at 105°C for 6 hours in an electric oven. Nitrogen content in 500 mg dry tuber powder was analysed using a Kjeltex System 1002 Apparatus, Tecator Co., Sweden.

(3) Selection for high yielding ability by using K_2O/N ratio in the 1st year clone population from polycross seeds

1) Selection in the 1st year clone population in 1982

Five thousand three hundred and forty-two true seeds from polycrosses among 11 varieties were sown in an electric-heated nursery bed in a plastic house. One thousand nine hundred sixty cuttings from each seedling were planted in a field with a plastic film mulch on 11th, May, and were first harvested on 12th to 13th, July. Seven hundred and eleven seedlings were selected on the basis of vine and tuber characters. Ten vine cuttings of each selected seedling were again planted in the field on 13th, July. The 711 first year clones were harvested for the time from 27th to 29th, October, and 267 clones were selected on the basis of the following criteria: number of marketable tubers, tuber yield, tuber shape, skin and flesh color of tubers, and susceptibility to diseases in the field. Dry matter, potassium and nitrogen content of tubers was measured by the procedures mentioned above. One hundred and twenty nine clones with high dry matter content, low potassium content, low nitrogen content and high K_2O/N ratio were selected. "Heritability in the broad sense" of the characters of tubers was estimated from variance within the 1st year clone population and variance within a clone used as male or female parent variety.

2) Performance of tuber yield of the 2nd year clones in 1983

One hundred twenty-nine 2nd year clones were planted with 11 parents in two plot replications with 32 plants per plot on 19th, May, and were harvested on 7th-8th, October. Fresh and dry tuber yield, dry matter, starch, potassium content and K_2O/N

ratio in tubers were measured by the procedures described above. Nitrogen content in 1000 mg dry tuber powder was analysed using a Kjeltac Auto System 1030 Apparatus, Tecator Co., Sweden. Relationship between the characters of tubers in the 1st year clones and in the second year clones was investigated.

Results

(1) Relationships between tuber yield and K₂O/N ratio, and other tuber characters in 58 varieties including those used for the A and B trials in 1980

Table 1 shows the correlation coefficients between tuber yield and K₂O/N ratio, and other tuber characters. The K₂O/N ratio showed a positive correlation with fresh and dry tuber yield, and a negative correlation with the nitrogen content in dry tubers. The nitrogen content in dry tubers showed a negative correlation with tuber yield and dry matter content. The K₂O content in dry tubers showed a negative correlation with

Table 1. Correlation coefficients between tuber yield and K₂O/N ratio, dry matter content, K₂O and nitrogen content in dry tubers of 58 varieties including the materials of the A and B trials in 1980

Character	NDT	KDT	DMC	DTY	FTY
K ₂ O/N ratio	-0.747**	0.134	0.002	0.445**	0.449**
N% in dry tuber (NDT)		0.486**	-0.355**	-0.513**	-0.402**
K ₂ O% in dry tuber (KDT)			-0.649**	-0.281*	-0.060
Dry matter content (DMC)				0.255	-0.093
Dry tuber yield (DTY)					0.936**
Fresh tuber yield (FTY)					

* significant difference at 5% level

** significant difference at 1% level

Table 2. Correlation coefficients between tuber yield and K₂O/N ratio, nitrogen and K₂O content, dry matter and starch content, in tubers of 39 varieties (1981 trial)

Character	SC	DMC	KDT	KFT	NDT	NFT	SY	DTY	FTY
K ₂ O/N ratio	0.243	-0.012	-0.051	-0.119	-0.894**	-0.943**	0.522**	0.505**	0.555**
Starch content (SC)		0.873**	-0.556**	0.389*	-0.480**	-0.123	0.604**	0.558**	0.374*
Dry matter content (DMC)			-0.703**	0.386*	-0.311	0.107	0.318	0.308	0.075
K ₂ O% in dry tuber (KDT)				0.356*	0.427**	0.162	-0.197	-0.231	-0.038
K ₂ O% in fresh tuber (KFT)					0.178	0.384*	0.125	0.113	0.018
N% in dry tuber (NDT)						0.905**	-0.573**	-0.563**	-0.536**
N% in fresh tuber (NFT)							-0.443**	-0.435**	-0.501**
Starch yield (SY)								0.990**	0.959**
Dry tuber yield (DTY)									0.968**
Fresh tuber yield (FTY)									

* significant difference at 5% level

** significant difference at 1% level

Table 3. Correlation coefficients between fresh tuber yield and K₂O/N ratio, nitrogen and K₂O content in dry tubers, dry matter and starch content in tubers of the 267 first year clones selected on the basis of the number of marketable tubers, tuber yield and disease resistance from the 711 first year clones derived from polycrosses among 11 varieties

Character	SC	DMC	KDT	NDT	FTY
K ₂ O/N ratio	-0.520**	-0.556**	0.497**	-0.682**	0.123
Starch content (SC)		0.870**	-0.465**	0.202*	-0.150
Dry matter content (DMC)			-0.769**	-0.005	-0.197
K ₂ O% in dry tuber (KDT)				0.268**	0.154
N% in dry tuber (NDT)					-0.035
Fresh tuber yield (FTY)					

* significant difference at 5% level

** significant difference at 1% level

Table 4. Estimates of "heritability in the broad sense" for the number of marketable tubers, tuber yield, dry matter content, K₂O and nitrogen content and K₂O/N ratio in tubers variance components within the 711 and 267 first year 2nd planting clones obtained from polycross seeds among 11 parent varieties and variance components within clones used as male or female parent varieties

Combination		No. of clones	No. of market. tubers	Tuber yield	No. of clones	Dry matter content	K ₂ O content	N content	K ₂ O/N ratio	No. of parent plots
Female	Male									
Kanto 72 (A) ¹⁾		56	82.7 ²⁾	87.7 ²⁾	26	94.2 ³⁾	77.5 ³⁾	38.5 ³⁾	59.5 ³⁾	6
Kanto 75 (A)	p	42	59.2	70.0	17	93.2	87.3	87.9	76.0	4
Gifu 1 (A)	o	57	76.3	81.3	28	80.6	54.9	82.5	68.3	6
Kogane-sengan (B)	l	56	53.9	82.7	22	91.0	54.3	75.4	45.7	6
Minami-yutaka (B)	y	103	87.8	86.6	33	94.4	75.1	67.7	40.8	6
CS 69136-33 (B)	c	97	75.7	53.0	29	85.2	53.4	22.1	22.5	6
Chikei 7130-2 (B)	r	90	42.7	65.2	29	95.3	81.4	67.4	81.5	6
Chikei 7195-10 (C)	o	69	74.3	85.4	29	94.0	90.3	68.8	73.7	6
Tamayutaka (C)	s	35	49.9	64.5	11	91.2	57.0	66.9	68.7	4
Kanto 33 (C)	s	16	81.7	87.9	8	73.4	44.3	87.2	87.3	2
Kanto 84 (C)		90	79.3	75.7	35	88.8	81.1	60.4	72.3	6
Mean & total		711	69.4	76.4	267	89.2	68.8	65.9	63.3	58

$$\text{Notes "Heritability in the broad sense"} = \frac{V_{F1} - V_E}{V_{F1}} = \frac{V_{FAi} - \frac{1}{2} \left(V_{Ai} + \frac{\sum V_{Bj} + \sum V_{Ck}}{8} \right)}{V_{FAi}}$$

V_{FAi} : phenotypic variance within the 1st year 2nd planting clones from polycross seeds obtained from the A_i variety used as female parent belonging to the A group of cross-incompatibility.

V_{Ai} : phenotypic variance within parent clone used as female belonging to the A group of cross-incompatibility.

$\sum V_{Bj} + \sum V_{Ck}$: Total value of phenotypic variance within parent clone used as male belonging to the B and C groups of cross-incompatibility.

¹⁾ roman letters in parenthesis indicate the cross-incompatibility group.

²⁾ estimated from the 711 first year clones obtained from polycross seeds.

³⁾ estimated from the 267 first year clones selected on the basis of the number of marketable tubers, tuber yield and disease resistance from the 711 first year clones.

dry matter content, and a positive correlation with the nitrogen content in dry tubers. These correlation coefficients were significant at 1% level. The K_2O/N ratio and nitrogen content in dry tubers were closely related with tuber yield, while the K_2O content in the dry tubers was closely related with the dry matter content.

(2) Relationships between tuber yield and K_2O/N ratio, and other characters in tubers of 39 varieties in the 1981 trial

Table 2 shows the correlation coefficients between tuber yield and K_2O/N ratio, and other tuber characters. The coefficient for the correlation between K_2O/N ratio and nitrogen content, and tuber yield, and those between K_2O content in dry tubers and dry matter and starch content were similar to those observed in the 1980 trial.

(3) Relationships between tuber yield and K_2O/N ratio, and other characters in tubers of the 267 first year clones selected from the polycross population

Table 3 shows the correlation coefficients between fresh tuber yield and K_2O/N ratio, and other tuber characters. The coefficients for the correlation between tuber characters were similar to those observed in the 1980 and 1981 trials, except for the relationship between fresh tuber yield and K_2O/N ratio.

(4) "Heritability in the broad sense" of K_2O/N ratio and other characters of tubers

Table 4 shows the "heritability in the broad sense" of the number of marketable tubers and tuber yield which was estimated from the variance component within the 711 first year clones obtained from polycross seeds and the variance component within a clone used as male or female parent variety. Estimates of "heritability in the broad sense" for the number of marketable tubers and tuber yield averaged 69.4 and 76.4 percent, respectively.

"Heritability in the broad sense" of dry matter, K_2O and nitrogen content, and K_2O/N ratio was estimated from the variance component within the 267 first year clones and the variance component within a clone used as male or female parent variety. Estimates of "heritability in the broad sense" for dry matter, K_2O and nitrogen content, and K_2O/N ratio averaged 89.2, 68.8, 65.9 and 63.3 percent, respectively.

(5) Relationships between tuber characters of the 129 first year clones in 1982 and of the second year clones in 1983

Table 5 shows the correlation coefficients between the tuber characters of the 129 first year clones with 11 parent clones and those of the same second year clones with 11 parent clones. Fresh tuber yield of the 129 second year clones was closely related with fresh tuber yield and K_2O/N ratio and nitrogen content in dry tubers of the same

Table 5. Correlation coefficients between characters of tubers of the 129 clones with 11 parent clones in the 2nd year and 1st year after seedling establishment

Character		Correlation coefficient
Second year clone	First year clone (in 2nd planting)	
FTY	FTY	$r=0.420^{**}$
FTY	K_2O/N ratio	$r=0.409^{**}$
FTY	NDT	$r=-0.235^{**}$
K_2O/N ratio	K_2O/N ratio	$r=0.348^{**}$
NDT	NDT	$r=0.508^{**}$
KDT	KDT	$r=0.453^{**}$
DMC	DMC	$r=0.793^{**}$
DMC	KDT	$r=0.566^{**}$

** significant difference at 1% level

Note FTY : fresh tuber yield

NDT : nitrogen content in dry tubers

KDT : K_2O content in dry tubers

DMC : dry matter content

K_2O/N ratio : in tubers

1st year clones.

Correlation coefficients between tuber characters of the 1st year clones in 1982, and of the 2nd year clones in 1983, were arranged in the order 0.793, 0.508, 0.453 and 0.348 for dry matter, nitrogen and K_2O content, and K_2O/N ratio, respectively. Correlation coefficient between dry matter content of the 2nd year clones and K_2O content in the dry tubers of the 1st year clones was 0.566. All these coefficients were significant at 1% level.

Discussion

TSUNO and FUJISE (1965) reported that in sweet potato plants grown in various culture solutions there was a close relationship between tuber weight and K_2O/N ratio in the tubers. A high K_2O/N ratio in the tubers was correlated both with a low ratio of water soluble nitrogen to total nitrogen content and with a low total nitrogen concentration in fresh tubers. They attached a great importance to the K_2O/N ratio in sweet potato tubers from the physiological viewpoint. In this report emphasis was placed on the estimation of the yielding ability of different genotypic clones based on the K_2O/N ratio and nitrogen content in tubers.

(1) Relationships between the characters of tubers

From the results of the 1980 trial with 58 varieties, and 1981 trial with 39 varieties, it was evident that in the high yielding varieties the total nitrogen content in fresh and dry tubers was extremely low, the K_2O/N ratio in tubers was high and the K_2O content in dry tubers was comparatively low. Also in the varieties with a high dry matter content in the tubers K_2O content in the dry tubers was extremely low while the nitrogen content was comparatively low.

In the trial of the 267 first year clones from polycross seeds, the calculation failed to reveal significant correlation coefficients between fresh tuber yield and K_2O/N ratio, and nitrogen content in dry tubers as shown in Table 3. The coefficients were estimated from the value of characters of tubers analyzed in the 267 first year clones which were selected on the basis of the number of marketable tubers, tuber yield and disease resistance from 711 first year clones derived from polycross seeds. The absence of a significant correlation coefficient can be ascribed to the fact that the clones with high nitrogen content in the tubers were rejected due to their low tuber yield.

(2) "Heritability in the broad sense" for tuber characters

Sweet potato is a hexaploid plant among self- and cross-incompatible species. In general, most of the sweet potato varieties are self-incompatible and/or sterile. Self-incompatibility is one of the outcrossing mechanisms present in flowering plants that lead to a high level of heterozygosity in a population of seedlings (HERNANDEZ and MILLER; 1962, MARTIN; 1965). We were able to observe large variations in populations of clones from seedlings. We consider that "heritability in the broad sense" could be estimated from the variance component within clones from seedlings derived from polycross seeds obtained from each parent variety used as female, and the variance component within parent clones used as male or female. Estimates of "heritability in the broad sense" for the number of marketable tubers and tuber yield averaged 69.4 and 76.4 percent, respectively.

Fig. 1. Relationship between fresh tuber yield in the population of the 2nd year clones and nitrogen content of dry tubers in the 2nd planting population of the 1st year clones.

Note 1: Tama; Tama-yutaka, Kogane; Kogane-sengan, Minami; Minami-yutaka, Gifu; Gifu 1, K 33; Kanto 33, K 72; Kanto 72, K 75; Kanto 75, K 84; Kanto 84, C 7130; Chikei 7130-2, C 7195, Chikei 7195-10, CS; CS 69136-33.

2: Numerals in open circles indicate the number of clones in a quadrant divided by a horizontal line corresponding to 0.5% N content in the 1st year clones and a vertical line corresponding to 200 Kg/a of fresh tuber yield in the 2nd year clones.

Fig. 2. Relationship between fresh tuber yield in a population of the 2nd year clones and K_2O/N ratio of tubers in the 2nd planting population of the 1st year clones.

Note 1: Variety name is the same as that indicated in Fig. 1.

2: Numerals in open circles indicate the number of clones in a quadrant divided by a horizontal line corresponding to K_2O/N ratio of 3.5 in the 1st year clones and a vertical line corresponding to 200 Kg/a of fresh tuber yield in the 2nd year clones.

Fig. 3. Relationship between fresh tuber yield in a population of the 2nd year clones and fresh tuber yield in the 2nd planting population of the first year clones.

Note 1: Variety name is the same as that indicated in Fig. 1.

2: Numerals in open circles indicate the number of clones in a quadrant divided by a horizontal line corresponding to 160 Kg/a of fresh tuber yield in the 1st year clones and a vertical line corresponding to 200 Kg/a of fresh tuber yield in the 2nd year clones.

Estimate of "heritability in the broad sense" for dry matter content, K_2O and nitrogen content, and K_2O/N ratio averaged 89.2, 68.8, 65.9 and 63.3 percent, respectively. These results suggest that most of the phenotypic variance in these characters can be ascribed to genotypic variance.

As shown in Table 5, dry matter, nitrogen and K_2O content, fresh tuber yield and K_2O/N ratio in tubers of the 1st year clones were closely related with those of the 2nd year clones. These results also suggest that most of the variation in these characters is controlled by genetic factors. This fact may also be taken as an illustration of the large "heritability in the broad sense" of these tuber characters.

(3) Effect of selection for tuber yield based on K_2O/N ratio and nitrogen content in tubers

In the population of the 129 first and second year clones obtained from polycross seeds with 11 parent variety clones, the relationships between fresh tuber yields of the 2nd year clones, and the nitrogen content in dry tubers, K_2O/N ratio in tubers and tuber yield of the 1st year clones are shown in Fig. 1, Fig. 2 and Fig. 3, respectively. These correlation coefficients were -0.235 , 0.409 and 0.420 , respectively.

In Fig. 1, 2 and 3, we drew a horizontal line on a level of value, *i.e.* 2.5 percent nitrogen content in dry tubers, K_2O/N ratio of 3.5, and 160 kg/a of fresh tuber yield in the population of the 1st year clones. We determined the level of the horizontal line on the following assumption. When we selected a clone at the level of the tuber characters in a population of the 1st year clones, five clones out of 31 second year clones with a yield exceeding 200 kg/a fresh tuber were rejected as they yielded less than 200 kg/a.

From these figures, selection efficiency of the 2nd year clones with fresh tuber yields exceeding 200 kg/a could be deduced. If a 1st year clone with a low nitrogen content in tubers of less than 0.5 percent, a high K_2O/N ratio exceeding 3.5 and a high tuber yield above 160 kg/a is selected, the selection efficiency for a high tuber yield above 200 kg/a in the second year clones is 26/97, 26/77 and 26/99, respectively.

It is concluded that the K_2O/N ratio and nitrogen content in tubers are very important indices for selection for tuber yield in sweet potato breeding.

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かんしょ育種における塊根収量に対する選抜形質としての K_2O/N 比の利用

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かんしょ育種において, 実生年次やその翌年次の塊根収量の評価は, 実生から得られる個体数が少ないため, 正しく行われにくい. そのため, 個体数が多くなる実生3~4年次以降にならないと塊根収量に対する選抜が有効とならない. 津野・藤瀬(1985)は塊根中の窒素含量が低くて K_2O/N 比の大きい品種が塊根収量の高いことを4品種を用いて確認している. 本報告は多数の品種を用いて, 上記2形質が塊根収量に対する選抜形質としての利用の可否を検討した.

58品種(1981年)と39品種(1982年)とを用いて, 塊根収量と塊根の諸形質の関係をみた. その結果, 塊根中の K_2O/N 比と塊根収量の間には正の相関, 塊根中の窒素含量と塊根収量・でん粉収量との間及び, 塊根中の切干歩合と加里含量の間に負の相関が認められた.

11品種間の多交配種子に由来する267系統の集団と母本・父本に用いた品種の試験区とで, 塊根中の切干歩合, 加里含量, 窒素含量, K_2O/N 比について, 分散成分から広義の遺伝力を推定した. その値はそれぞれ89.2, 68.8, 65.9, 63.3パーセントであった. また, 129系統と親に用いた11品種で, 上記4形質の実生年次と実生第2年次の値の間の相関係数は有意で, それぞれ0.793, 0.453, 0.508, 0.348であった. これらの結果から, これら形質の主な部分は遺伝的支配を受けていることを示した. さらに, 実生年次の K_2O/N 比, 窒素含量, 塊根収量と実生第2年次の塊根収量との相関係数は有意で, それぞれ0.409, -0.235, 0.420であった. すなわち, 実生年次に高い K_2O/N 比, 低い窒素含量の系統は, 実生第2年次に高い塊根収量を示し, K_2O/N 比と窒素含量は実生年次の塊根収量の選抜形質として用いることができることを示した.

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