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The Growth of Apios (*Apios americana* Medikus), a New Crop, under Field Conditions*

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Abstract : To investigate the growth of apios (*Apios americana* Medikus) under field conditions, the sequential increase in the dry weights of shoot and underground part from April to November 1993 was monitored. Seed tubers weighing 3-4 g (fresh weight) were planted in a Tohoku University experimental field. The emergence of buds on the ground occurred 30 days after planting (DAP). Dry weights of vine and leaf increased progressively 98 days after planting, reached a maximum by 168 DAP, and then declined for the remainder of the growing season. The initiation of new tubers along the rhizomes took place by 68 DAP, but progressive enlargement occurred after maximum shoot growth or after the peak of flowering. The growth of new tubers might have stopped as the plant wilted by 217 DAP. Seed tuber (mother tuber) of apios did not degenerate. Its dry weight gradually decreased until maximum shoot growth, and then increased when tuber growth became predominant. The weight of the seed tuber at the end of the growth was similar to that at planting. It was suggested that these results could be used as a basis of knowledge on apios growth which would be of use in its cultivation.
Key words : Apios, *Apios americana* Medikus, Field conditions, Growth, Rhizome, Seed tuber, Shoot, Underground part.

新作物アピオス (*Apios americana* Medikus) の生長経過について：星川清親・ジュリアルニ（東北大学農学部）

要　旨：アピオス（*Apios americana* Medikus）の栽培化を目的として，まず本研究では圃場で栽培したアピオスの生長過程を明らかにした．1993年4月に，生体重3—4gの平均的サイズの種いもを圃場に植えた．植え付け後約30日で出芽した．地上部の乾物重の増加は，植え付け後98日目ごろから急激になり，乾物重は168日目ごろに最大値に達し，その後低下した．地下部について見ると，68日目ごろに，地下茎の各節が肥大を始めて，いも形成が始まり，地上部の生長が終わるころ又は開花盛期以後，いもは急速に肥大した．植え付け後217日に地上部は降霜により枯れ，いもの生長はここで止まった．種いもは消失せず，植え付けから地上部の生長が終わるごろまで，乾物重が低下し，それ以後急速に増大して，収穫時には植え付け時の重さとほぼ同じになった．本研究によりアピオスの圃場条件下での生長を始めて明らかにすることができた．これは今後の栽培技術研究の基本となる．
キーワード：アピオス，*Apios americana* Medikus，生長，地下茎，地下部，地上部，種いも，圃場条件．

Apios or American groundnut (*Apios americana* Medikus) is a tuber-bearing leguminous plant which is native to and distributed throughout eastern North America. Although historically the tuber was used as food by the North American Indians and was also consumed by early European settlers[13], apios was never domesticated. Indians did not grow the plant in a cleared field, but protected and encouraged the growth of the wild stands[14]. During the potato famine of 1845, there was an effort to cultivate apios in Europe, but this was abandoned when the possibility of growing potato become feasible[1]. Though it has been forgotten for a long time, recently, the potential of apios for domestication as a food crop has lately been discussed[2].

It is said that apios was introduced to the northern area of the Tohoku District about 100 years ago for unknown reasons. A farmer in this area used apios for postnatal medication and to relieve fatigue, and it was also used to keep children healthy. It was Hoshikawa who tried to cultivate this plant for about 10 years and named the new crop plant Apios. By his efforts, recently, cultivation of the crop has become widespread in Japan, especially in Tottori, Akita, and Miyagi prefectures[5,6].

Even though literature on morphology[11], cytology[3,13] and nutrient content[10,15,16,17] of apios has been reported, there is no information about its growth under field conditions. This study was done to investigate the growth of apios under field conditions by observing changes in dry matter accumulation and some

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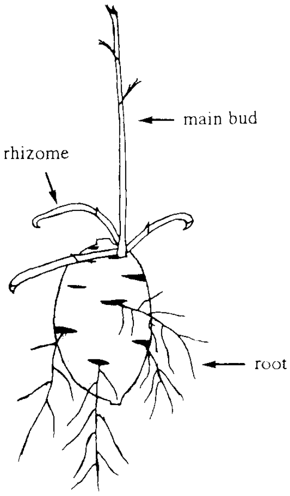

Fig. 1. Sprout performance at emergence.

of the developmental changes of the plant part during the growing period.

Materials and Methods

The experiment was carried out at Tohoku University from April to November, 1993. Tuber, 3-4 g in weight, was used as seed tuber. Planting depth was 5 cm. Plant spacing was 100 cm between rows and 20 cm within rows. At planting plot was fertilized with 4.8 g/m^2 of $(NH_4)_2SO_4$ (21% N), 17.1 g/m^2 of $Ca(H_2PO_4)_2 \cdot CaSO_4$ (17.5% P_2O_5), 7.5 g/m^2 of KCl (60% K_2O). Forty two days after planting (DAP) 18 m the long net was stretched between sticks inserted at a width of 140 cm about 150 cm above the soil surface.

Plant samples were collected 5 times, at an interval of 5 weeks, starting from 63 DAP. At each sampling, 3 plants in the area of 100 cm×60 cm in 3 replications were carefully removed. Plant was separated into shoot (vine and leaf) and underground part (root, seed tuber and new tuber). The plant parts were oven dried for 3-4 days at 60°C and weighed.

Results and Discussion

1. Shoot growth

Buds emerged at about 1 month after planting. Several buds were formed at one side of the upper part (shoulder) of the tuber, but only one bud developed into the aboveground shoot. The others developed into rhizomes along which new tubers were produced (Figs. 1 and 2).

The main bud continued to elongate to 16 cm until it produced one compound, fully

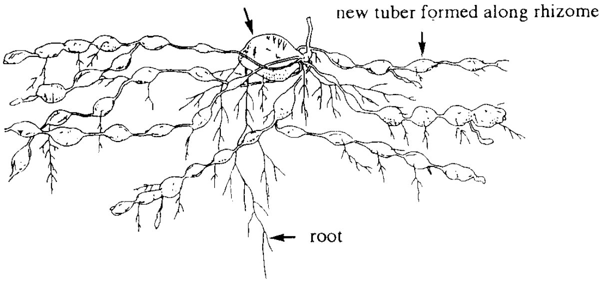

Fig. 2. Growth habits of underground part.

expanded leaf at 44 DAP. Generally, the 1st fully expanded leaf was found at the 2nd or 3rd nodes from the base of the plant and the leaflet numbers observed were 3 or 5. Those developed from the 4th node to apex had 5 or 7 leaflets. Nine or 11 leaflets were rarely developed in the plant.

The anti-clockwise twining vine continued climbing on net, intertwining, and reached the top of net by 98 DAP. The average length of the main vine and leaf numbers were about 150 cm and 19, respectively. About 23 tillers (1st and 2nd tillers) with a 200 cm total length were developed in the plant. By 120 DAP, the main vine was 240 cm long, the total tiller length (1st and 2nd tillers) was 530 cm, and 70 tillers (1st and 2nd tillers) and 80 leaves had developed in the plant (data not presented). At this time, the plant grew vigorously and had already covered the net. The observation of vegetative growth of the plant after 120 DAP could not be done due to the heavily twining of plant.

Figure 3 shows the dry weight accumulation of vine, leaf, and vine+leaf (shoot) during growth. The growth of these upperground part appeared to follow a sigmoid curve with time. In the early stage of growth, i.e. until 98 DAP, the dry weight of the vine and leaf were at a minimum. Towards the middle of the growing season, i.e. from 98 to 168 DAP, dry weight increased, and then declined at the end of growth. Changes in the total dry weight of vine and leaf during the growth showed the same pattern as those of the vine or leaf itself. The decline in the average leaf and vine dry weight during the latter part of the growth is thought to be caused by the accumulation of dry matter in the tuber.

2. Underground part growth

Figure 4 shows the changes in dry weight of underground part during the growth. Growth

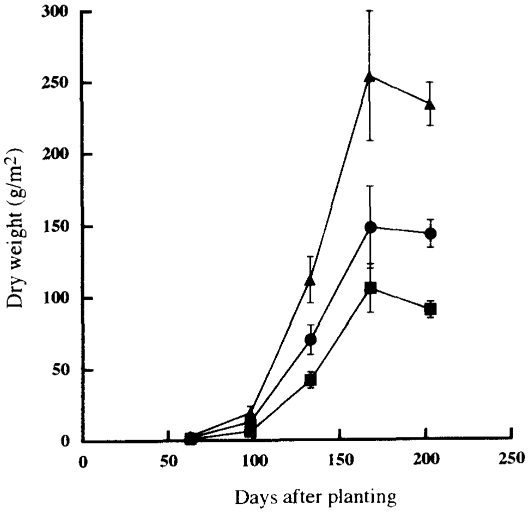

Fig. 3. Changes in vine (■), leaf (●), and vine+leaf (▲) dry weights during the growth. Vertical bars indicate standard errors.

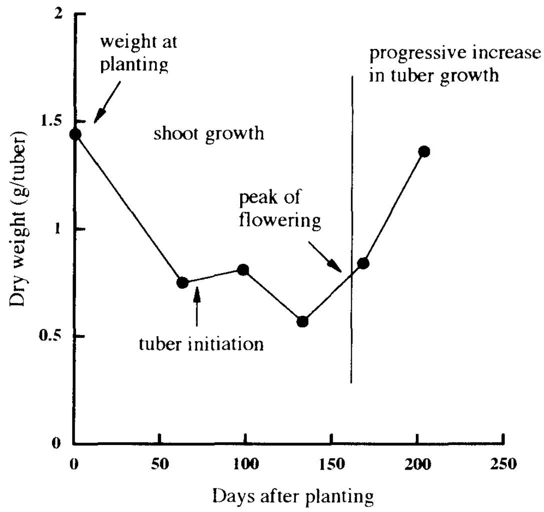

Fig. 5. Changes in seed tuber dry weight during the growth. Standard error bars not included as values were small.

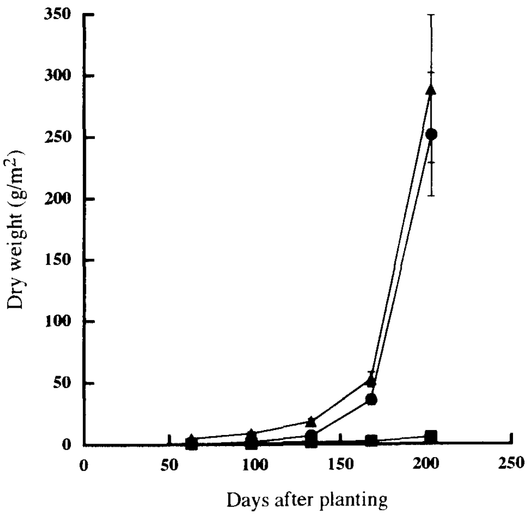

Fig. 4. Changes in root (■), new tuber (●), and underground part (▲) dry weights during the growth. Vertical bars indicate standard errors.

pattern of the underground part and the new tuber were similar. New tuber dry weight contributed the greatest portion of the underground part. There was an increase in root dry weight during the growth period, but the rate of increase was lower than that of the new tuber. About 5 or 6 roots developed at dark-brown spot like areas which were distributed over the surface of the seed tuber. Numerous roots were also found at each node of the rhizomes. A lot of root nodules developed both at the seed tuber roots and at the roots of the rhizomes.

The new tuber initiated early in the growing season, i.e. by 68 DAP, but their progressive enlargement did not start until 168 DAP. Progressive enlargement of new tubers commenced after peak of flowering (165 DAP) and continued until the final sampling. It is likely that the time from emergence to tuber initiation was influenced by the vigorous vine and leaf growth which delayed tuber enlargement. But as the tuber developed, competitive effects appeared between the growing tubers and shoot. At this period, new tubers were the dominant competitor for assimilate. By 203 DAP the new tuber represented 50% of the total plant dry weight (data not presented). It is likely that new tuber enlargement stopped by 217 DAP due to shoot wilting. It appears the rate of assimilation of dry matter and its allocation within the plant was the critical component affecting yield of apios.

3. Seed tuber (mother tuber) growth

Concerning the seed tuber (mother tuber) growth, there were 2 patterns of dry weight changes during the growing seasons (Fig. 5). First, there was a decrease in dry weight from planting to about maximum shoot growth (168 DAP). Thereafter, dry weight increased until 203 DAP. The decline was possibly caused by the usage of nutrient contained in seed tuber for early shoot growth, while the increase was probably caused by accumulation of dry matter as a result of second development in seed tuber. Thus, at the end of the growth, weight of seed tuber (mother tuber)

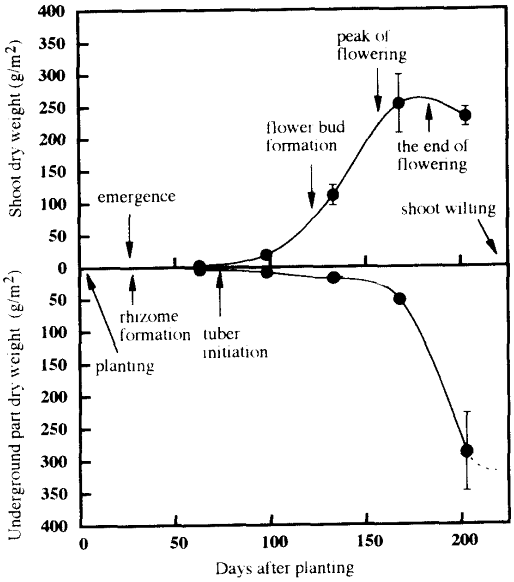

Fig. 6. Concept of growth pattern of apios under field conditions. Vertical bars indicate standard errors.

was shown to be relatively the same as that at planting. Kodama et al.[7] reported that the seed tubers of sweet potato thicken themselves into big anomalous tubers after a decrease in weight during shoot growth. They further reported[8] that total nitrogen content of seed tuber gradually decreased as the sprout grew until 80 days after planting and increased thereafter. In contrast with seed tuber growth of apios, the growth of the seed tuber of potato[4,9] and Chinese yam[12] continued to degenerate until the end of the growth. Although the plant parts which become new tuber are the same between apios and potato or Chinese yam, i.e. from stem, the seed tuber growth pattern was different. The pattern of seed tuber growth of apios was similar to that of sweet potato seed tuber.

In another experiment concerning the growth of mother tuber (1 year seed tuber), we found a small increase in dry weight at the end of the growing period compared with that at planting. It was assumed that the tuber would grow bigger if it was used as seed tuber for several years. Whether significant advantages would be derived from using mother tuber as seed tuber continuously is not currently known. Further study is needed to investigate the effects of mother tuber growth and yield.

4. Concept of the apios growth under field conditions

Figure 6 shows the concept of apios growth during the growing season under field conditions. This figure was obtained by plotting the data of shoot (vine+leaf) and underground part dry weights. Based on this figure, in general, the growth of apios under field conditions could be separated into three phases, as follows: (1) pre-emergence growth phase (planting-emergence), which involves the establishment of root using the material stored within the mother tuber; (2) growth phase, in which shoot growth is dominant (emergence-168 DAP); and (3) the period of tuber growth (68 DAP-217 DAP). The stages which were closely interrelated and overlapped with that of shoot growth. In conclusion, this explanation of growth was obtained under our field conditions. Differences in growth pattern could be observed if conditions in which the experiment was conducted differ from those which have been explained, but it is hoped that this growth picture for apios can provide a basis of knowledge upon which further research on cultivation can be done.

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