

# Distribution and fruit yield of *Actinidia kolomikta* (Maxim. et Rupr.) Maxim. in the northern part of Chuo Alps, Japan

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## Summary

In order to obtain basic ecological information on *Actinidia kolomikta*, as an initial step to use it as a local product, we collected strains in the northern part of Chuo Alps, Japan. The distribution area and habitat environment, as well as variation of fruit morphology and yield were investigated. We collected 10 strains at an elevation of 1420 to 1830 m. Each habitat was located on a slope facing a river, mostly at the edge of a riparian forest. The average fruit weight of 10 strains was 1.09 g (0.35–1.65 g) and there was little variation in fruit shape. Allometric analyses revealed a high correlation of average fruit weight with fruit length and diameter. Fruit yield shown by the efficiency of gathering, which is expressed as a logarithmic value of the number of collectable fruits per hour, ranged from 0.04 to 2.22 (1.1–165.3 g·hr<sup>-1</sup>). Both average fruit weight and maximal fruit yield were only a quarter of those in *A. arguta* in the same research area. The relationship between elevation and average fruit weight and between elevation and fruit yield, showed a convex curve with an optimal elevation at around 1600 m.

**Key words :** *Actinidia kolomikta*, Chuo Alps, Elevation, Fruit, Yield

## 1. Introduction

In recent years, non-wood forest products (NWFPs) have gained attention in forest conservation. NWFPs include forest goods, e.g. foodstuff and medicine, which can be unique local products produced without felling (Mantau et al., 2007). This means that NWFP will promote local development, imposing little burden on forest environment.

Kiwifruit (*Actinidia chinensis*) has become a worldwide cultivated species from a mere local NWFP utilized at a low frequency, within an extraordinary short time. The genus *Actinidia*, liana species in forest, distributes in high altitudinal temperal and subtropical zones in East Asia (Ogaki, 1983a). Kiwifruit, whose wild species was indigenous to China, is the most famous among *Actinidia* species domesticated as edible fruit. The seeds of wild kiwifruit was brought into New Zealand via Europe from china in 1904, cultivated commercially from 1934, and rapidly spread worldwide (Ogaki, 1983a). In Japan, kiwifruit was introduced into the area where citrus fruits had been overproduced. Thus, kiwifruit is a peculiar fruit tree which is now cultivated worldwide, without extensive selection (Ferguson, 1991 ; Hirsch et al., 2001).

Consequently, kiwifruit is susceptible to diseases, insects and weather disaster (Ogaki, 1983b ; 1994). In Japan, closely related native species such as *A. arguta*, *A. rufa*, and *A. polygama* have been studied from the viewpoint of rootstocks, hybridization or infection source (Ushiyama et al., 1992 ; Phivnil, et al., 2004 ; Nitta and Narabe, 2007). These problems need to be solved to increase the producing area of kiwifruit.

*A. kolomikta*, also a native species in Japan, has several desirable attributes such as outstanding chilling tolerance, precocity, and extraordinary high vitamin C content (Ogaki, 1983a ; Ferguson, 1991 ; Nishiyama, 2007). The fruit itself is small but delicious like kiwifruit and *A. arguta*, and the hairless fruit

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Received January 8, 2010

Accepted February 3, 2010

skin is beneficial for eating the fruit raw and for food processing (Liu et al., 1998). In mountainous regions, *A. kolomikta* will be an important food resource for wild animals, because the number of plant species is limited. Takahashi et al. (2008) reported that *A. arguta* fruit is eaten in large amounts by Japanese black bears in autumn, and almost all the seed was undigested and excreted in their droppings. This indicates the relationship between *Actinidia* species and animals, the plant provides food to the animal which in turn helps the plant disperse.

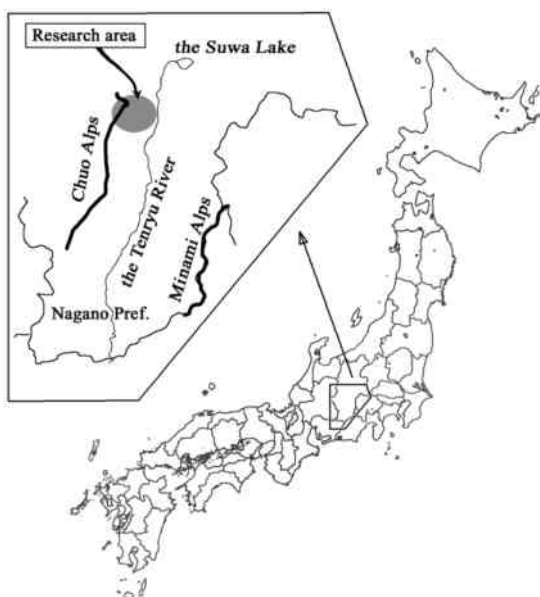
The research on plant resources needs to receive more attention in the country of its origin because the conservation of species or its habitat might be blurred in the near future by the recent global environmental changes. In the original habitat, we can easily collect the field data of the species with a geographical advantage. However, there is little information available on *A. kolomikta* in Japan. On the other hand, in Europe, the desirable attributes of *A. kolomikta* especially the chilling tolerance and high vitamin C content have spurred the research on its components in fruit, tissue culture, and breeding (Kola and Pavelka, 1988 ; Kovac, 1993 ; Hirsch et al., 2001 ; Liu et al., 2004 ; Xiao et al., 2004 ; Ferguson, 2007). It seems unfortunate that the research is less active in the country of its original habitat than in the countries it has been imported.

The purpose of this paper is to report the basic ecological information about *A. kolomikta*, as an initial step to use it as a NWFP. We describe the distribution, habitat environment, variation of fruit morphologies and yield of *A. kolomikta* by collecting the strains in the northern part of Chuo Alps, Japan.

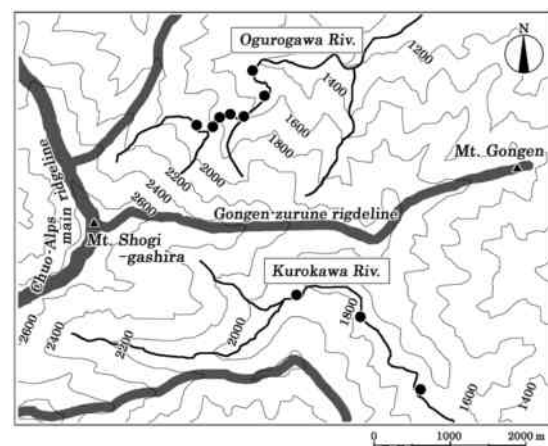
## 2. Methods

### 2.1. Collecting strains

*A. kolomikta* strains were collected in October 2009. We restricted the research area to the basin of Ogurogawa River and Kurokawa River, the Northern part of Chuo Alps (Figure 1 and 2), considering the high elevation of its distribution. However, it would be difficult to determine whether the elevation, geographical features or the genetic properties of the local population is the crucial factor, even if some variations were detected by a large-scale research. After detecting fructified *A. kolomikta* population, the fruits which had become soft and edible were collected. The location was recorded using a handy GPS and topographic maps.



**Figure 1** Research area, the northern part of Chuo Alps.



**Figure 2** The sampling points of *A. kolomikta*.

## 2.2. Habitat environments

Habitat environments including the elevation, outline of topography, vegetation profile and flora, were surveyed simultaneously when each strain was collected. The elevation was determined using a handy GPS and topographic maps.

## 2.3. Fruit weight and size

We measured the weight and size (fruit length and fruit diameter) of 6 fruits from each strain. Fruit diameter was calculated by averaging the lengths of the major and the minor axes. In order to inspect the changes in fruit size and shape with the increase of fruit weight, allometric relations were analyzed between the fruit weight and fruit size.

## 2.4. The efficiency of gathering and fruit yield

As a component of fruit yield, we used the efficiency of gathering (Arase and Uchida, 2009a). This index, a simple and easy method of field survey, is to grade the class mark of logarithmic number of fruits collectable per hour. The grade was marked at 0.5 intervals in a common logarithm transformation as follows ;

0 : from 1 to 3,

0.5 : from 4 to 9,

1.0 : from 10 to 31,

1.5 : from 32 to 99,

2.0 : from 100 to 316,

2.5 : from 317 to 999 (fruits•hr<sup>-1</sup>).

Fruit yield can be expressed as the product of the average fruit weight and the efficiency of gathering. Since the latter is expressed as a logarithmic value, we applied the same transformation to the former to obtain the following equation,

$$\log(\text{fruit yield}) = \log(\text{average fruit weight}) \\ + \text{the efficiency of gathering,}$$

where the unit is g•hr<sup>-1</sup> (Arase and Uchida, 2009a).

In this study, fruit yield was calculated by using above equation. Then, the correlations of elevation with average fruit weight and fruit yield were examined by scatter diagrams and correlation analyses. The significance of coefficient of determination in each approximation model was judged by an F-test.

## 3. Results

### 3.1. Collected strains and habitat environment

Ten strains of *A. kolomikta* were obtained at an elevation of 1420 to 1830 m (Figure 2 and Table 1). The habitat of *A. kolomikta* including the populations without flower or fruit setting, was at an elevation of 1200 to 2000 m in our observation. Even in the range of elevation where we collected the fructiferous strains, populations without flower or fruit setting were often observed.

Nine out of ten habitats we observed were in riparian forests, facing a river. Figure 3 illustrates an example of the vegetation profile. Various tree species were dominant ; *Abies veitchii* and *Tsuga diversifolia* as conifers, *Acer* spp., *Betula* spp., and *Cercidiphyllum magnificum* as broad-leaved trees. There was a Japanese larch (*Larix kaempferi*) forest, which faced riparian forest and was also on a slope close to a river.

Various herb species were also dominant in the herb layer. Commonly observed species were *Artemisia princeps*, *Calamagrostis hakonensis*, and *Carex dolichostachya*. The bamboo grasses dominant in the surroundings, *Sasa senanensis* and *Sasamorpha borealis*, were not detected in any of the habitats.

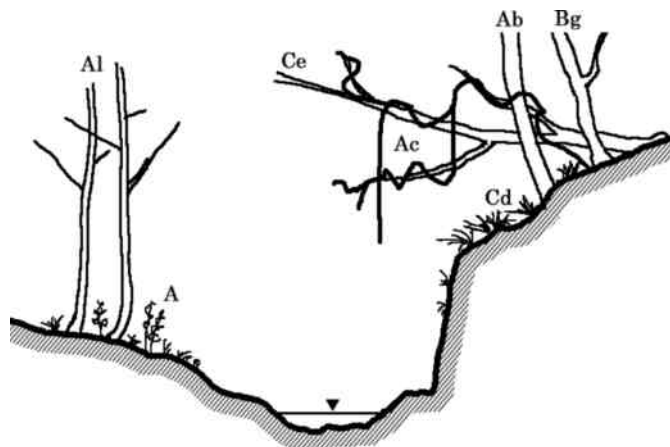
Table 1 Collected strains and the habitat environments of *A. kolomikta*.

River system	Elevation (m)	Vegetation	Dominant species		Other lianas***
			Tree layer*	Herb layer**	
Ogurogawa River	1420	a riparian forest	Aa, H, P, Q	A, C, D	S, V
	1520	a riparian forest	Ce, E, P	A, C	V
	1600	a riparian forest	Af, Ce, Ti, Ts	A, C	-
	1650	a riparian forest	Af, Am, Bg, Ts	A, C	S
	1700	a riparian forest	Ab, Af, Bg, Ce	A, Cd, D	-
	1750	a riparian forest	Bg, Ce, Ts	C	-
	1820	a riparian forest	Ab, Ac, Bg, Ce	A, C	S
Kurokawa River	1590	a Japanese larch forest	Ab, Au, L	C, Cd, D	Ac, S
	1700	a riparian forest	Ab, Au, Ce, Ts	C, Cd	S
	1830	a riparian forest	Ab, Au, Be, Ce	A, C, Cd, D	S

\* Aa : *Acer argutum*, Ab : *Abies veitchii*, Al : *Alnus firma*, Am : *Acer mono*, Au : *Acer ukurunduense*, Be : *Betula ermanii*, Bg : *Betula grossa*, Ce : *Cercidiphyllum magnificum*, E : *Euptelea polyandra*, H : *Hydrangea paniculata*, L : *Larix kaempferi*, P : *Pterocarya rhoifolia*, Q : *Quercus mongolica*, Ti : *Tilia japonica*, Ts : *Tsuga diversifolia*

\*\* A : *Artemisia princeps*, C : *Calamagrostis canadensis*, Cd : *Carex dolichostachya*, D : *Dryopteris crassirhizoma*

\*\*\* Ac : *Actinidia arguta*, S : *Schizophragma hydrangeoides*, V : *Vitis coignetiae*



**Figure 3** A vegetation profile of *A. kolomikta* habitat, at an elevation of 1700 m along Ogurogawa River. A : *Artemisia princeps*, Ab : *Abies veitchii*, Ac : *Actinidia kolomikta*, Al : *Alnus firma*, Bg : *Betula grossa*, Ce : *Cercidiphyllum magnificum*.

Although the co-existing lianas, *A. arguta* and *Vitis coignetiae* were found at a lower elevation, only *Schizophragma hydrangeoides* was observed at an elevation higher than 1600 m.

### 3.2. Fruit size and yield

Table 2 shows the fruit size and yield of each strain. The fruit weight of 10 strains ranged from 0.35 to 1.65 g with an average of 1.09. Fruit yield using the efficiency of gathering, expressed as a logarithmic value, averaged 1.56 (0.04–2.22), i.e., 36.3 g·hr<sup>-1</sup> (1.1–165.3 g·hr<sup>-1</sup>). The difference between values along the 2 river sides was not significant (Wilcoxon's rank sum test). The ratio of fruit length to fruit diameter, an index of fruit shape, was around 1.5 in most strains, but beyond 2.0 (slender) in 2 strains (Table 2 and Photo 1). This ratio was not significantly related with elevation, average fruit weight and fruit yield (F-test).

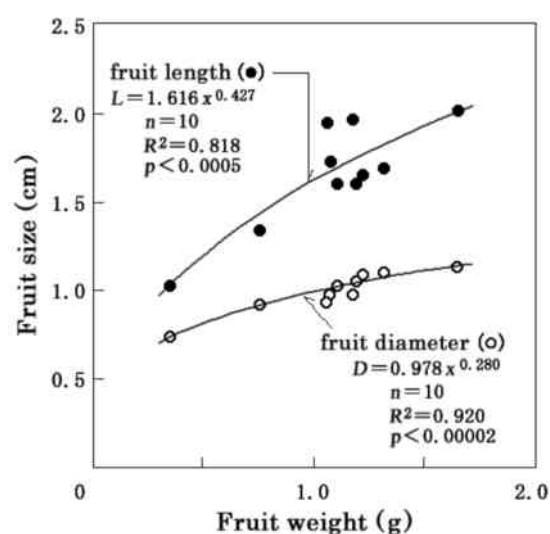
Figure 4 indicates the relations between average fruit weight and fruit size. The relations were significant in both fruit length ( $R^2=0.818$ ,  $p<0.0005$ ) and fruit diameter ( $R^2=0.920$ ,  $p<0.00002$ , respectively), in which the size increased along certain diminishing-returns curves as the fruit weight increased.

Table 2 Fruit size and yield in each strain of *A. kolomikta*.

River system	Elevation (m)	Average fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit shape (length /diameter)	Efficiency of gathering (log (fruits·hr <sup>-1</sup> ))	Fruit yield (log (g·hr <sup>-1</sup> ))
Ogurogawa River	1420	1.10	1.60	1.01	1.59	1.5	1.54
	1520	1.08	1.73	0.97	1.78	1.5	1.53
	1600	1.23	1.65	1.09	1.53	2.0	2.09
	1650	1.19	1.62	1.05	1.55	2.0	2.08
	1700	1.06	1.95	0.93	2.09	2.0	2.03
	1750	1.32	1.69	1.09	1.55	1.5	1.62
	1820	0.35	1.03	0.73	1.41	0.5	0.04
Kurokawa River	1590	1.65	2.01	1.13	1.79	2.0	2.22
	1700	1.18	1.97	0.98	2.02	1.5	1.57
	1830	0.75	1.34	0.92	1.46	1.0	0.88



**Photo 1** Variation in the fruit morphology in *A. kolomikta*. The upper-side fruits were harvested from an elevation of 1830 m along Kurokawa River, and the lower-side ones from an elevation of 1700 m along Ogurogawa River. The background patterns are 1-centimeter squares.



**Figure 4** Relation between the weight and size of *A. kolomikta* fruit. Each plot shows the average value in each strain.

### 3.3. Relations between fruit yield and elevation

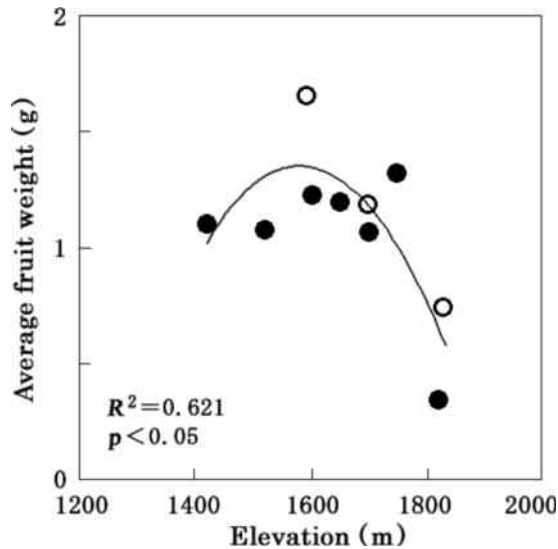
The relation between elevation and average fruit weight is shown in Figure 5, and that between elevation and fruit yield in Figure 6. Since each scatter diagram showed a curved relation which seemed convex, we approximated the data by a function of higher-order of elevation. As a result, the components of the first and the second orders were significant (F-test), and the coefficients of determination in the quadratic approximations were  $R^2=0.621$  ( $p<0.05$ ) in average fruit weight, and  $R^2=0.771$  ( $p<0.01$ ) in fruit yield. In each of them, the elevation giving the maximum estimation was around 1600 m.

## 4. Discussion

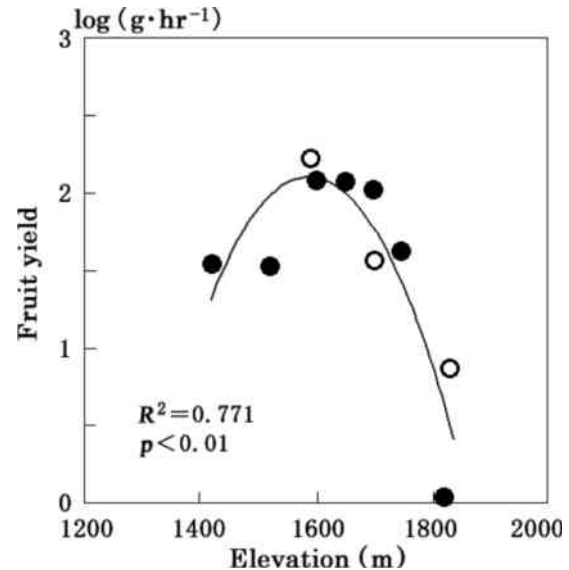
### 4.1. Distribution and habitat environment

The distribution and fructiferous area of *A. kolomikta* were confirmed to be located in the highest elevation zone among the species of the same genus. The elevation of the distribution area of *A. kolomikta* was from 1200 to 2000 m, and that of the fructiferous area from 1420 to 1830 m (Figure 2 and Table 1). As for the other *Actinidia* species in the same research area, Arase and Uchida (2009a, b) reported that edible or medicinal fruits of *A. arguta* were collected at an elevation from 770 to 1400 m and those of *A. polygama* from 520 to 1330 m. Therefore, *A. kolomikta* occupied the highest area, which suggests the





**Figure 5** Relations between the elevation of *A. kolomikta* habitat and its average fruit weight. The solid and open circles show the strains from the basins of Ogurogawa River and Kurokawa River, respectively.



**Figure 6** Relations between the elevation of *A. kolomikta* habitat and its fruit yield. Fruit yield was derived from the average fruit weight and the efficiency of gathering. The solid and the open circles show the strains from the basin of Ogurogawa River and Kurokawa River, respectively.

highest chilling tolerance.

*A. kolomikta* is considered to be an important edible fruit species in a higher elevation area. Hardy kiwifruit (*A. arguta*) and Japanese wild grape (*Vitis coignetiae*) were found as co-existing lianas at a lower elevation of the *A. kolomikta* distribution area (Table 1). The area that Japanese wild grape set fruit was reported to range from an elevation of 1100 to 1600 m in the same research area (Arase et al., 2008). On the other hand, only *Schizophragma hydrangeoides* was observed at an elevation higher than 1600 m (Table 1). The fruit of this species is not a good food resource, because it is an achene containing anemochore seeds. In our observation, only the small trees of *Vaccinium* species (wild species of blueberry in Japan) set edible sweet sap fruit, in the area higher than the elevation from around 1900 m to the ridgeline of alpine zone beyond the forest line. Therefore, *A. kolomikta* was considered to be an important food resource for animals in autumn, in the interval zone between *Vitis coignetiae* (below an elevation of 1600 m) and *Vaccinium* trees (above 1900 m).

The habitat of *A. kolomikta* resembled that of *A. polygama* in its topography and vegetation; every habitat was on a slope facing a river, in a forest edge (Table 1). The habitat of *A. arguta* ranged from a valley to a ridge, whereas that of *A. polygama* was restricted to a valley (Arase and Uchida, 2009ab). In general, kiwifruit is susceptible to drought because of its shallow root system (Ogaki, 1984). Judging from the topography, that is, the valley is humid and ridge dry, *A. kolomikta* seemed to be similar to *A. polygama* in the poor tolerance to drought.

#### 4.2. Fruit size and yield

The disadvantage of inferior productivity of fruit was pointed out for *A. kolomikta*. The average fruit weight of 10 strains was 1.09 g and the maximal fruit yield was 165.3 g·hr<sup>-1</sup>, which were only a quarter of those in *A. arguta* fruit at the appropriate harvest season (Arase and Uchida, 2009b). A slight variation in fruit morphology was observed in fruit shape (Table 2 and Photo 1), but the fruit shape was not significantly correlated with elevation, average fruit weight and fruit yield. Because of its small fruit size and small number of data, the variation in fruit shape and its ecological meaning were not determined.

Since the inferior productivity restricts the fruit supply, it is difficult to market the raw or processed fruit at present. *A. kolomikta*, however, possesses desirable attributes, such as the ability to tolerate a cool climate (Ogaki, 1983a ; Ferguson, 1991 ; Nishiyama, 2007). The research to bring out the use of *A. kolomikta*, as a rootstocks of kiwifruit and genetic resource for hybridization, would be practical at present.

#### 4.3. Relations between fruit yield and elevation

The relation of elevation with average fruit weight and fruit yield proved that the optimal elevation was around 1600 m (Figure 5 and 6). This result suggests that it is efficient to seek the strains with excellent fruit weight and yield in *A. kolomikta* in the mountainous area at an elevation of approximately 1600 m. The optimal elevation, which gave the maximum fruit yield to the liana species setting edible sap fruit in our research area, varied with the species. The optimal elevation for *A. polygama*, *A. arguta*, *Vitis coignetiae* and *A. kolomikta* was around 950, 1100, 1300 and 1600 m, respectively (Arase et al., 2008 ; Arase and Uchida, 2009ab). Such a difference would be quite important for us to gather wild plant resources and for wild animals in mountainous and sub-alpine zones to find food resources. An area where both resource density and resource predictability are high is worth defending as human territory (Dyson-Hudson and Smith, 1978). Our result demonstrates that the optimal elevation for the fruit yield varies with the species, which implies certain relations with the locality or gathering area of plant resources for human being (Ikeya, 1988), and with the seasonality of vertical movement for wild animals (Izumiyama et al., 2009).

In a higher elevation zone, various phenomena related to cold temperature occur. There are several reports on the relations between reproduction of trees and elevation ; e.g. reduction of flower sets (Taira et al., 1991), delay of inflorescence period (Nagasawa and Sato, 1958 ; Komatsu et al., 1998), and increase or decrease of pests (Ushiyama et al., 1991). The distribution area of *A. kolomikta* in this study was 1600 ± 400 m (±2.4 C in a rough calculation), fixing the basis of the optimal elevation in fruit yield. This difference in temperature was supposed to be one of the important factors for the flower or fruit setting, fruit weight and yield. Furthermore, seed germination, initial vegetative growth, years necessary for flowering, periodicity of bearing and pollinator in the cool sub-alpine zone remain as the key issues to be clarified in order to cultivate *A. kolomikta*.

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中央アルプス北部におけるミヤマタタビ (*Actinidia kolomikta*  
(Maxim. et Rupr.) Maxim.) の分布と果実収量

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要 約

ミヤマタタビ (*Actinidia kolomikta*) の地域産物化をはかる手始めとして生態的な基礎的知見を得るため、中央アルプス北部において系統収集を試みた。分布域と自生地を把握するとともに、果実のサイズと収量を調査した。得られた系統数は10、自生地の標高は1420~1830m、地形は沢に面した斜面で、溪畔林の林縁が多かった。平均果実重は系統平均1.09 g (0.35~1.65 g) で、果形の系統間変異がわずかに認められた。果実における相対生長関係の分析から、果実重と果実長および果実径との間に強い関係が認められた。採集効率 (1時間あたり採集可能数の対数階級値) を用いて収量を求めたところ、0.04~2.22 (1.1~165.3 g・hr<sup>-1</sup>) で、平均果実重、最大の収量ともに同地域におけるサルナシ (*Actinidia arguta*) の約4分の1であった。標高と比較すると、平均果実重および収量は、いずれも標高1600m付近を最大値とする上に凸の曲線関係を示した。

キーワード：ミヤマタタビ，中央アルプス，標高，果実，収量