Trends and Problems of Konjak (*Amorphophallus konjac*) Cultivation in Japan

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The konjak has been grown as one of the most important industrial crops at hillside villages since old times in Japan.

According to the recent statistics,[4,5] Jinenjo and Uedama cultivations have an area of 1,222 ha and 14,108 ha respectively, and the total production reaches about 100,000 tons, equivalent to 19,300 million yen as country-wide gross earnings.

Jinenjo is a kind of konjak cropping in which primary plants (cormlets) and older plants (from 2nd to 4th year corms) are grown mixed in disorder. It is like a semi-natural vegetation. In late autumn, only older corms are harvested for sales and the others are left in the fields all year round. Cultural practices are simple and primitive with only mulching with wild herbs, weeding and spraying pesticides one or two times.

On the contrary, Uedama is a cultivation with intensive management. Seed corms are grouped by ages and planted separately. After harvesting, older corms are used for sales, but others are stored in groups by corm ages on warm shelves during winter. Intensive cultivation such as heavy application of chemical fertilizers, herbicides, and pesticides, and mechanical management is made during the course of growing.

Although the corm yields per unit land area have been increased by the increased application of these inputs, various diseases, namely Fuhai (caused by *Erwina carotovora*), Hagare (*Xanthomonas conjac*), Negusare (*Rhizoctonia solani*) etc. have come to increase recently. Besides, growth retardation caused by continuous cropping become conspicuous widely. As a results, corm quality (mannan contents) is getting worse. Recent trends that konjak cropping is enhanced in flat fields rather than in hillside fields might have caused by a need for high cultural efficiency required for modern agriculture, because the cultural efficiency can easily be increased in the former.

However, Jinenjo which is found mainly in hillside fields has many excellent features as follows:

1) Continuous cropping for more than a hundred years is frequently observed. 2) The plants have no diseases, and cormlets are suitable for seeds. 3) Corm can be saled at high prices due to their good quality. 4) Steeply declined fields are maintained successfully by the cultural practices from a viewpoint of field-ecosystems.

The purpose of this paper is to propose principles of future improvement of Uedama konjak cultivation as suggested by the ecology of Jinenjo.

Natural environment and cultivation of Jinenjo[1)]

Jinenjo is distributed geographically from northern parts of Miyazaki Prefecture (Latitude 33°N) in Kyushu to southern parts of Fukushima Prefecture (Latitude 37°N) in Honshu, the mainland of Japan, as shown in Fig. 1.

Areas where Jinenjo konjak is growing or might had been grown are considered to have most suitable natural environment. Similarity of natural environment of Jinenjo fields as

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Fig. 1. Geographical distribution of Jinenjo in Japan.
Note: Size of circle indicates relative number of villages.

described below will prove this deduction to be true.

1) Climatic factors

Climatic factors of Jinenjo fields are summarized in Table 1.

Annual mean temperature is about 13°C. In addition, warm index shows 100–110 (°C×month) and cold index is within a range from −3 to −9(°C×month). Annual precipitation varies with localities to some extent, but precipitation during a period from May to October, just covering the growing periods of konjak, is almost constant within a range of 1,000–1,200 mm.

Most of Jinenjo fields decline to south or south-east direction at inclination of 25–35° as indicated in Table 2. These land features have a close relation with sunshine hours and insolation intensity as suggested by Ozawa[2,3]. According to his report, sunshine hours are shorter and the amount of solar radiation incident is smaller on the ground declined towards south than that towards north in summer, while the reverse relation is found in winter. This fact gives a main reasons why Jinenjo fields are distributed in such hillside areas.

2) Edaphic factors

Edaphic factors are summarized in Table 2. Geology of the surface layers of Jinenjo fields belongs to Paleozoic and parent materials

Table 1. Climatic factors of Jinenjo konjak fields in Honshu, the mainland of Japan

Prefecture	Meteorological observatory*		Annual mean air-temperature	Warm index	Cold index	Precipitation (mm)		
	Location	Altitude				Annual	May–October	November–April
		m	°C	°C · month				
Fukushima	Higashidate	155	12.8	101	−9.0	1,408	1,008	400
Ibaraki	Daigo	110	13.0	104	−7.8	1,413	1,017	396
Tochigi	Bato	133	12.9	102	−7.4	1,438	1,038	400
Gunma	Manba	380	13.1	104	−6.8	1,317	1,076	241
Saitama	Chichibu	218	13.4	107	−6.4	1,369	1,078	291
Tokyo	Hikawa	364**	13.3	104	−4.4	1,614	1,265	349
Yamanashi	Uenohara	270**	14.1	113	−3.4	1,583	1,149	434
Nagano	Toyooka	440	12.1	95	−9.5	1,913	1,252	661
Okayama	Osa	345	13.2	104	−5.9	1,870	1,173	697
Hiroshima	Tsutsuga	290**	13.0	104	−8.2	1,995	1,266	724
Yamaguchi	Hirose	130	14.5	108	−3.2	2,404	1,593	811
(Average)			13.2	104	−4.3	1,666	1,174	492

* The nearest one to each Jinenjo field surveyed.
** The altitude of Jinenjo fields is more than 200 m.

Table 2. Edaphic factors of Jinenjo konjak fields in Honshu, the mainland of Japan

Field location	Latitude & altitude	Land features		Geography[1)] & Parent materials	Sedimental patterns	Soil texture of surface and second layer	Index of simple classification for soil productivity[2)]
		Declined direction	Degree of inclination				
Hanawa, Fukushima	36°54′ 300m	SE	22°	P Sedimentary rocks	Colluvial	loamy to clay clay	III_{tdise} $II_{gp(w)fn}$
Daigo, Ibaraki	36°44′ 200m	SSW	31	P Sedimentary rocks	Colluvial	clay gravelly	III_{dpg} II_{tnse}
Okutama, Tokyo	35°48′ 900m	SE	34	P —	—	gravelly	—
Kosuge, Yamanashi	35°46′ 650m	SSE	34	P —	—	gravelly	—
Toyooka Nagano	35°33′ 700m	SE	35	Tn Sedimentary rocks	Colluvial	loamy loamy	$III_{(w)se}$ II_{tgfn}
Osa, Okayama	35°06′ 430m	S	30	M Metamorphic rocks	Colluvial	loamy to clay loamy to clay	III_{se} II_{dfn}
Tsutsuga, Hiroshima	34°38′ 320m	SSE	25	P Sedimentary rocks	Residual	clay clay	II_{tdfs} —
Nishiki, Yamaguchi	34°18′ 300m	S	22	P Metamorphic rocks	Residual	medium clay medium clay	IV_sIII_{ne} $II_{tgp(w)fa}$

Note 1) P: Palaeozoic Era, Tn: Tertiary period (Neogene), M: Mesozoic Era.
2) Roman numerals (II, III......) indicate degrees of limitation for crop production by edaphic factors expressed with small letter as follows. II: Moderate, III: Slightly severe, IV: Severe. t: depth in surface soil, d: depth in available soil, g: gravel contents in surface soil, p: hardness to ploughing, (w): soil dryness, f: natural fertility, n: abundance in soil nutrients, i: impediment, a: accident, s: degrees of field inclination, e: erosion.
In each location, upper index is for surface layer and lower one for second layer.

consist of sedimentary rocks usually. Top soil layers are generally thick in depth and rich in gravels. Soil drainage is very good, so that crop damage due to ill-drainage hardly occurrs. Soil fertility is not so high and water erosion occurrs frequently due to steep inclination. Soil textures are loamy or clay, especially stony loam is most common. Sedimental patterns are colluvium in ordinary cases.

3) Biological and ecological factors

Useful plants commonly found in the surroundings of Jinenjo fields are: Kiri (*Paulownia tomentosa*), *Urushi* (*Rhus verniciflua*), Kozo (*Broussonetia Papyrifera*), Mitsumata (*Edgeworthia chrysantha*), tea (*Camellia sinensis*Q, Kuwa (*Morus bombyics*) and Sugi (*Cryptomeria japonica*).

A typical example of Jinenjo field is shown in Fig. 2. Forests of Sugi usually grown on the upper parts contiguous to Jinenjo fields might serve not only to conserve soil water but also to protect Jinenjo against the damages caused by strong wind or severe coldness. Kozo, Mitsumata, Kiri and Kuwa are useful for shading sunshine, weakening insolation and decreasing climatic damages in summer. Tea trees are mainly used for soil conservation in surroundings of the fields.

4) Cultural practices

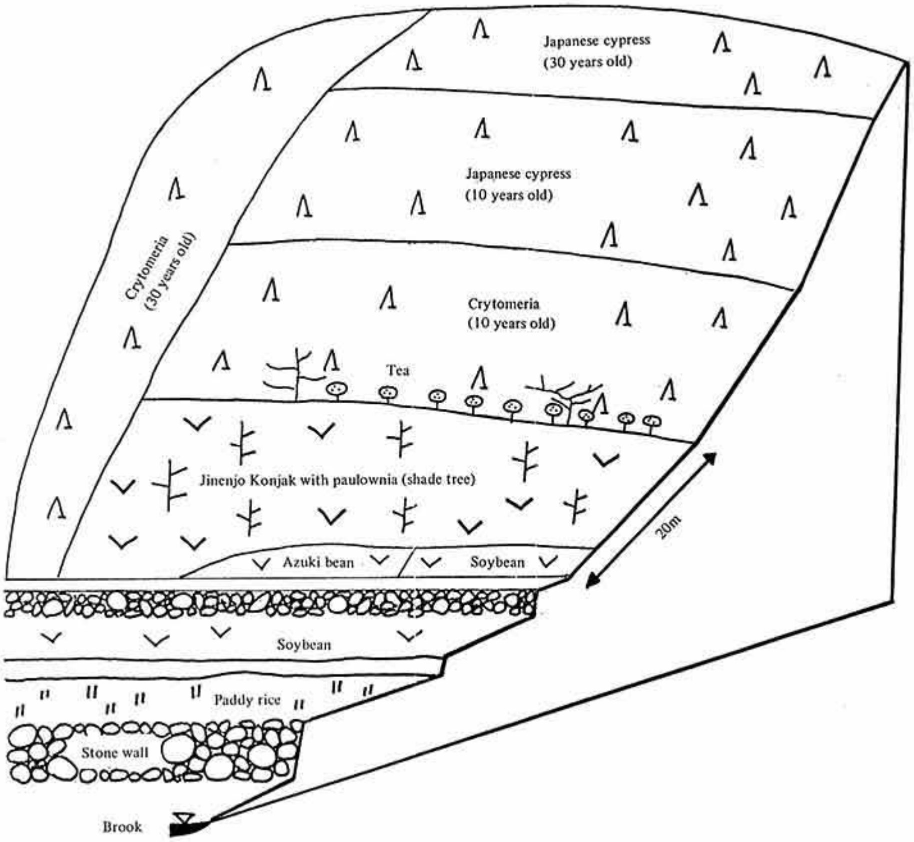

Fig. 2. Sketch of a typical Jinenjo field at Osakabe, Osa, Okayama Prefecture

Cultural practices in Jinenjo might have been in harmony with genetic characters of konjak and natural environments of such declined fields as mentioned above. Accordingly, each cultural technique must have a scientific implication, and can be regarded as ecologically adapted.

It is one of the salient features to mulch konjak fields with straws of rice, barley or wild herbs. The amount of mulching reaches 300–1,000 kg per 10a, though decreasing recently. This practice has an important role for soil conservation, weeding and nutrient supply to the konjak plants. Another distinctive feature of cultural techniques is a minimum use of modern agricultural chemicals such as fertilizers, pesticides or herbicides. This may be a reason why plants have no diseases, or corms are good in quality.

Problems of konjak cultivation

Konjak cropping shows a trend to increase in flat fields rather than in hillside ones. It means that the konjak cropping is increasing in areas of less favorable natural environment.

The natural environment can be classified as follows: (a) macroenvironment: the complex of environmental factors that are not, or not markedly influenced by the crop, and (b) microenvironment: the complex of environmental factors that depends to a large extent on the types and stages of development of the crop.

Cultural practices are to make plant growth favorable for obtaining higher corm yields. Favorable growth depends primarily upon the suitable macroenvironment, and secondarily

Table 3. Problems in Uedama cropping and measures to be taken for improvement

Features	Problems	Improvements
1. Climatic factors Excessive high temperature in summer Excessive sunshine in summer Excessive solar radiatin in summer No shading crops 2. Edaphic factors Excessive soil temperature Heavy application of chemical fertilizers neglecting farmyard manures Soil trampling by machinary Negligence of soil conservation 3. Biological and ecological factors No attention to field biome Contempt for ecological conservation	1. Susceptibility to various diseases 2. Increase in soil diseases and pests 3. Decline of corm quality 4. Growth retardation by continuous cropping 5. Defficiency in micronurients 6. Decline of soil fertility 7. Destruction of field ecosystems	1. Evaluation of cropping field from its natural and ecological environments 2. Selection of varieties 3. Introduction of companion crops 4. Control of soil temperature 5. Application of composts 6. Deep tillage 7. Planning on crop sequence 8. Maximum utilization of ecological techniques 9. Suitable conservation of field ecosystems

upon the cultural practices which improve microenvironment so as to be suited for plant growth. Modern konjak cultivation in flat fields encounters with worse macroenvironments, but these handicaps could be compensated by improving microenvironments with agricultural chemicals or machinery. However, this is not actually the case. There are many weak points in modern cultivation as shown in Table 3. The use of large amount of chemicals is apt to spoil konjak-field ecosystems.

In our investigation on Jinenjo, it was often heard that a spray of herbicides results in the death of Kiri, a shading tree, or application of chemical fertilizers results in enhanced diseases of the konjak plants. Perhaps, the ecosystems of Jinenjo fields might become unstable by these cultural practices.

In this connection, the author considers that it is important to find out ways and means to improve konjak cultivation by utilizing ecological principles of traditional Jinenjo cultivation. From this point of view measures for improvement as listed in Table 3 are proposed. How to implement these measures is considered to be a basic problem in konjak cultivation.

Recent trend is that more emphasis is placed on quantity rather than on quality of corms. But more attention should be paid to the quality, as konjak is an industrial crop.

Selection of varieties is another important problem. For Jinenjo cultivation in Shikoku and Kyushu districts, where somewhat warmer than Honshu, a cultivar Bittyu is grown frequently on fields with less favorable edaphic factors. There are some morphological and ecological differences among ecotypes of native varieties of Jinenjo. This fact must be ascertained in further tests, but at any rate varietal differentiation with localities is an important problem in the breeding program of konjak in Japan.

As for introduction of konjak into Okinawa Prefecture, Japanese varieties may fail to grow because of high temperature or typhoon attack there. Fortunately, there are several species suited for konjak manufacture like *Amorphophallus oncophyllus*, *A. variabilis* and others which originated in humid tropics or subtropics in southern Asia and in the Pacific. A preliminary test for adaptability of these *Amorphophallus* species collected widely from these areas is desirable.

In konjak cropping, excellent seed corms or cormlets are the basis for better harvesting. Some farmers at Yuki, Hiroshima Prefecture introduced seed corms (cormlets) from the Jinenjo at Osa, Okayama Prefecture, and obtained good results. The possible use of Jinenjo fields for seed corms production must

Plate 1. Scenery of Jinenjo vegetation.
A: Hashidate, Kosuge, Yamanashi Prefecture.
B: Osakabe, Osa, Okayama Prefecture. See Fig. 2.

be studied. Otherwise, Jinenjo will soon disappear due to its low productivity.

In conclusion, the ecological analysis of the traditional Jinenjo cultivation may offer useful information for the basic principle of future improvement of the Uedama konjak cultivation.

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