クズの栽培と利用:

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Review

Cultivation and Utilization of Kudzu-Vine

(*Pueraria lobata* Ohwi)

Adaptability, cultivation method, cutting frequency, yield, grazing and feeding value.

Hyoe TSUGAWA*

Information on taxonomy, geographical distribution, use, breeding and propagation of kudzu-vine was reviewed and summarized in the previous paper[50]. In this paper, the available information on adaptability, cultivation methods, cutting frequency, yield, grazing and feeding value of kudzu-vine is described. In addition, problems awaiting solution in the utilization of kudzu-vine for agriculture are pointed out and a course for future studies of kudzu-vine is mentioned as a way to solve these problems.

1. Adaptability

1) Climate

Kudzu-vine (represented as kudzu hereafter) has a wide climatic range. The northern

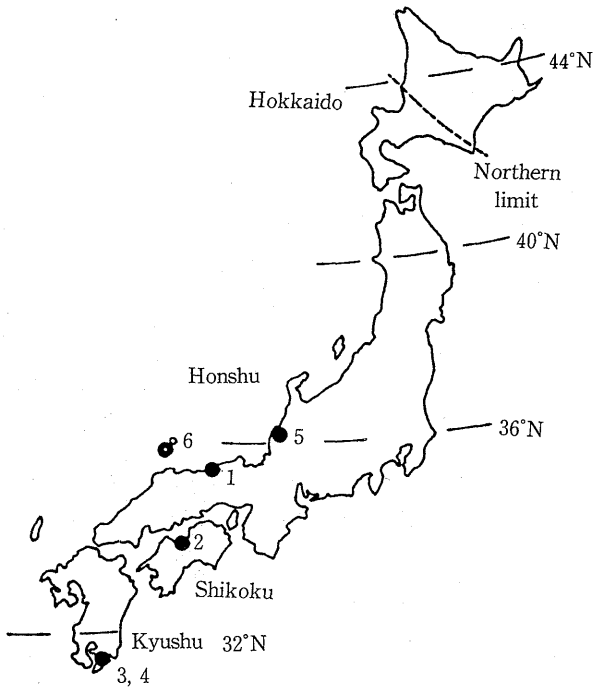

Fig. 1. Northern limit of kudzu distribution in Japan and the localities of strains in Table 4[2].

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limit of kudzu distribution in Japan is the line which connects Rumoi in Hokkaido(44°N)and Erimo-misaki in Hokkaido(42°31'N)(**Fig. 1**), corresponding approximately with an isothermal line of 7°C yearly mean temperature[25]. The altitudal distribution of kudzu in the various parts of Japan has been given by HORIKAWA[19], and it was observed that the altitude limit of kudzu distribution was about 1, 200 m above sea level in central Japan[19].

In the USA, kudzu can survive the winter south of the 45°N. Seed pods do not mature in the Columbia district of Missouri, situated at 38°51'N or in Washington, D.C. Kudzu flourished well in the area ranging from 30° to 35° N in southeastern USA[16]. This species has flourished well in Mississippi with 1, 200 mm in annual precipitation, whereas it does not grow wild in California with only 500 mm in annual precipitation, even though California is situated at the same latitude as Mississippi[10]. It is said that in the USA, to the north, minimum winter temperatures are probably most important to limiting growth of kudzu and toward the western limits of the range, decreased water availability becomes important in limiting growth[43]. Kudzu is distributed from Texas, Oklahoma, Missouri, Illinois, Kentucky, West Virginia, Pennsylvania and New Jersey to the coastal states along the Atlantic and the Gulf of Mexico[20] (**Fig. 2**).

Kudzu can be cultivated on a large scale in the humid subtropical conditions in Argentina[7]. It grows wild in the southern area of the northeastern district in China[16,28]. Kudzu cultivation was not successful in extremely arid regions in Algeria[30] and Puerto Rico[48]. However, it can grow in very dry climates that alfalfa and clovers can not withstand[16].

According to the results obtained from controlled indoor-environment experiments, a combination of day temperature of 33°C and night temperature of 30°C was found to be the

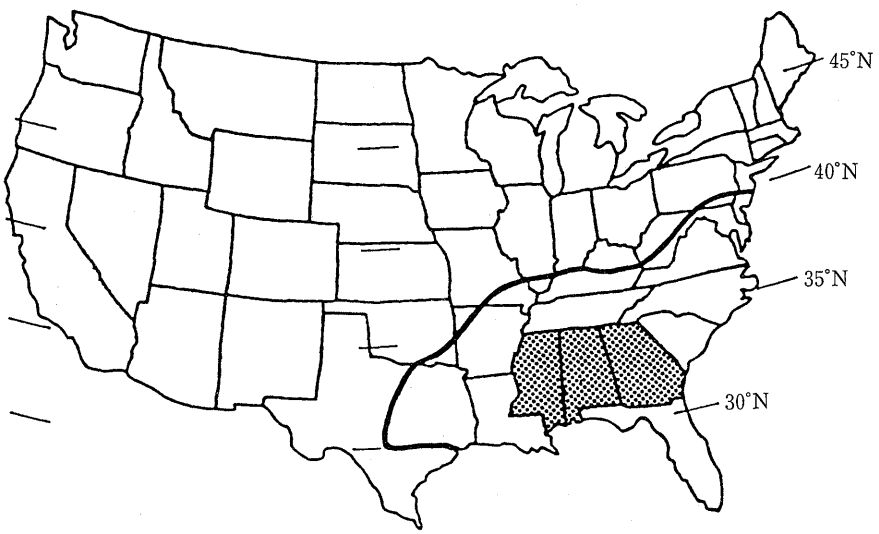

Fig. 2. Distribution range of kudzu-vine in the USA[20].
Note : The distribution range is inside the heavy line, and dotted part shows the states in which the luxuriant growth of kudzu-vine has been particularly marked.

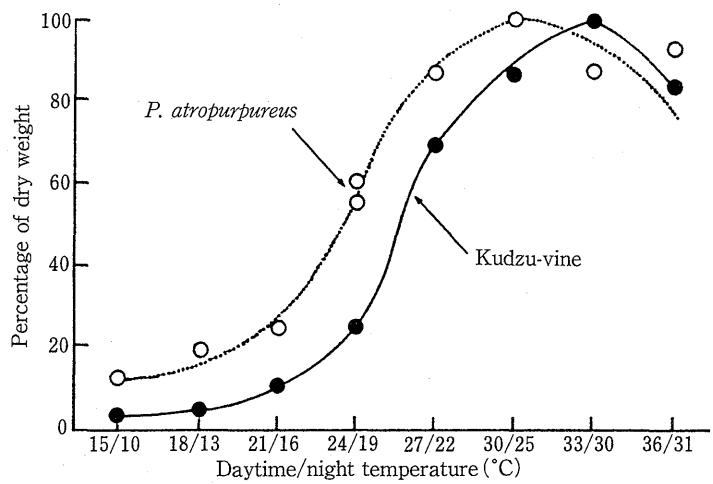

Fig. 3. Temperature responses of kudzu-vine and *Phaseolus atropurpureus*[24].
Note: Expressed dry weight at optimum temperature as 100%.

optimum for kudzu growth, but kudzu showed poor growth in the combination of day temperature below 24°C and night temperature below 19°C[24] (**Fig. 3**). Long days with high temperature at night were favourable to growth. During short days, relatively high temperature at night was more unfavourable for growth than lower temperature[32].

2) Soils

Kudzu grows well in a wide range of soil types, but it is difficult to grow in sandy places, poorly drained sites, heavy clay soils and base rock. However, kudzu will be able to grow in areas which are not always suitable for cultivation of alfalfa and clovers, as in soils of high acidity[16]. It grows best on well-drained loam soil of good fertility[57].

2. Cultivation method

1) Fertilizer application

Kudzu forms a symbiotic association with root nodule bacteria (*Rhizobium* sp.) belonging to the cowpea group[51]. Kudzu nodulates readily ; well nodulated roots have been noted even where no inoculum was added to the seed[49,52]. Kudzu can grow satisfactorily in the absence of fertilizers in productive areas ; however when cultivated, fertilizers are often applied at rates such as 760 kg barnyard manure, 19 kg superphosphate and 57 kg plant ashes per 10 a (1 are = 100 m^2)[33].

Phosphate is necessary for establishment of kudzu stands on extremely depleted soils as seen in the southern states of the USA. Maximum yield was obtained by application of 45 to 90 kg of superphosphate per 10 a. The response of kudzu to fertilizer has naturally varied between experimental sites, so different responses in yield and nutrient content to the application of lime and phosphorus have been recorded[1,12,40]. In general, phosphorus was the most important element for kudzu on heavy soils, while on light soils potash was also required[13].

2) Disease and insect damage

Angular leaf-spot disease due to *Cercospora puerariicola* infestation causes premature leaf-fall of kudzu. This disease comes from seed infection and scarifying by soaking in conc. H_2SO_4 has a possible disinfective action[55]. Other diseases are false rust due to *Synchytrium minutima,* summer blight due to *Pellicularia filamentosa,* leaf spot due to *Asscochyta* sp., rust due to *Phakopsora pachyrhizi*[38], soft root due to *Fusarium* sp[36]. and black patch due to a sterile fungus whose taxonomy is not yet determined[56].

Kudzu was severely damaged by velvetbean caterpillar (*Anticarsia gemmatalis*) in some parts of Alabama. Lead arsenate and calcium arsenate dusts applied at the rate of 0.9 and 1.1 kg per 10 a respectively were found to be the most effective controls[15]. Larvae of *Endoclyta* spp. burrow into the bases of thickened roots and of the stout stems, which are rich in starch, arising from the crowns of kudzu stumps. This may trigger the internal break-down of the stems and roots. The author regards Japanese beetle (*Popillia japonica*) as a harmful insect for kudzu.

3) Weeding

Cultivation was of value to eliminate competing vegetation during the early stages of kudzu growth[40]. Sodium trichloracetate (TCA) gave excellent results in suppressing weeds, such as crabgrass (*Digitaria sanguinalis*), on land devoted to kudzu seedling production at Thorsby, Alabama[62].

4) Sowing in mixture

Kudzu was sown in mixture with Rhodesgrass (*Chloris gayana*) and jaragua grass (*Hyparrhenia rufa*) in Uganda, and it looked very promising after one season of grazing[52]. Also excellent results were obtained in a mixture of kudzu with jaragua grass in Venezuela[23]. In Puerto Rico, trials were carried out to compare the productivity between kudzu alone and a mixture with para grass (*Brachiaria mutica*). The mixture was superior to kudzu alone in dry matter production with the application of superphosphate at the rate of 19 kg per 10 a[5].

Dent corn was planted with kudzu in the USA and good results were obtained[33]. In this case, the foliage produced from kudzu planted earlier was plowed under for green manure before sowing the dent corn. The kudzu, which had been tilled under, sprouted and climbed the stalk of the growing dent corn. Both crops were harvested together. Caley peas (*Lathyrus histus*) or crimson clover (*Trifolium incarnatum*) were sown in kudzu stands[4]. In Formosa, kudzu was sown in mixture with napiergrass (*Pennisetum purpureum*) or native *Miscanthus* sp[53].

3. Cutting frequency and yield

Cutting in the first year of growth is likely to be detrimental to a stand of kudzu because of its slow early growth[57]. If kudzu is cut once a year, it should be cut in August. When one-year old kudzu seedlings were planted at the rate of 1,200 plants per 10 a in an unfertilized field, the yield was from 2,113 to 2,394 kg of fresh weight per 10 a in August of the first year[29]. If there are two cuttings per year, the first cut should be made in June to July and the second in early October[29]. In another experiment[33], the cutting of kudzu was delayed till early September of the second year, in which case yield was 1,140 kg fresh weight per 10 a.

The yield of kudzu, which was cut twice, in late June and late August, was from 2, 090 to 2, 660 kg of fresh weight per 10 a. Fresh yield of kudzu cut 4 times per year was 5, 060 kg per 10 a[42].

Two cuts of kudzu taken in mid-June and mid-October had a maximum hay production of 456 kg per 10 a[16]. If the first cutting was made in June, and the second just before the first frost, hay yields of 500 kg per 10 a can be expected from good stands on a fertile soil. Average good hay contains about 50% leaf, and if it is carefully handled when cut, early hay will have as much as 60% leaf[57]. A well-established crop of kudzu produced 1,250 kg of airdry hay per 10 a[18].

Great difficulty is experienced when kudzu is cut for hay with an ordinary mower. Alabama Agricultural Experiment Station devised a method for overcoming this problem[9].

There is very little information available on the growth and yield of roots. The developing root systems of seedling have been examined[49] and the relationship between the number of cuttings and the root yields has been evaluated[39]. The roots of plants receiving six cuttings per season decreased in weight during a period of two years, those from plants receiving four cuttings increased about 150%, those from plants receiving two cuttings increased approximately 400%, and those from plants receiving one cutting increased about 1, 250%. However, at present there are very little data about old root systems of kudzu except for one example which was given by the author[60].

4. Grazing

Grazing trials in Alabama showed that one acre of kudzu provided sufficient grazing for one cow from May to September. Removing the cattle in early September was necessary for regrowth of the kudzu stand[3]. In grazing on kudzu stands during an eight-year period in Tifton, Georgia, gains per steer ranged from 568 to 735 g per day and from 34 to 157 kg per season[57]. Cattle preferred to graze on kudzu plots receiving higher rates of P and K fertilizers[31]. In grazing trials with heifers, the estimated carrying capacity was 0. 77 head per acre in the mixture of kudzu and paragrass (*Brachiaria mutia*), and 1.09 head per acre in the mixture of kudzu and guineagrass (*Panicum maximum*)[5,6]. In a pure stand of kudzu, kudzu plants should not be grazed until the third year. If they are grazed in the second year, the grazing should be very light[57].

5. Chemical components for feed and feeding value

Seasonal change of the crude protein content in kudzu foliage has been examined by some researchers (**Table 1**). The crude protein content was comparatively high during the early growing season. The content tended to decrease in July, increased in August and declined again in autumn. When kudzu was cut six times at monthly intervals from June 1st to November 1st, the crude protein content at the second cutting on July 1st to November 1st, the crude protein content at the second cutting on July 1st had a maximum value of 26. 7% in the leaves and of 14. 8% in the stems (**Table 2**). In another cutting experiment (**Table 3**), the first cuttings were made in a monthly sequence from June 1st to October 1st and all the second cuttings were made on November 1st. The crude protein content in the aftermath had

Table 1. Seasonal changes of crude protein in leaves and current year's stems of kudzu-vine.

Researcher / Plant part / Sampling data		Yoshida and Suzuki[61]		Kuriyama[29]		Miyamoto and Ōkawa*
		Leaf	Stem	Leaf	Stem	Leaf
Jun.	1	20.5	11.5			
	10			20.1	10.8	
Jul.	1	17.9	8.3			
	10			18.2	9.6	
	29					9.8
Aug.	1	18.6	9.4			
	10			18.6	9.4	
Sept.	1	18.9	8.3			
	2					12.0
	10			16.6	6.1	
	29					14.3
Oct.	1	17.9	7.6			
	28					7.6
Nov.	1	17.8	8.3			

* The data were quoted from Shiryo-seisan-gaku, written by Kikuchi *et al.*[26].

Table 2. Changes in crude protein content of leaves and current year's stems of kudzu-vine with cutting frequency[61].

Cutting frequency and cutting date		Crude protein content (%)	
		Leaf	Stem
First cutting	Jun. 1	20.4	11.6
Second	Jul. 1	26.7	14.8
Third	Aug. 1	19.4	12.3
Fourth	Sept. 1	24.6	10.9
Fifth	Oct. 1	23.6	*
Sixth	Nov. 1	*	*

* Analysis of crude protein was not carried out since the foliage had not yet regenerated sufficiently.

a maximum value of 26.1% in the leaves when the first cutting was made on September 1st and 12.3% in the stems when the first cutting was made on October 1st.

The crude fat content (**Table 4**) ranged from 2.6 to 4.1% in the leaves and from 1.2 to 1.7% in the stems during the period from June to October, and it tended to increase in both the leaves and the stems from July onward. The crude fiber content (**Table 4**) fluctuated in

Table 3. Effects of the first cutting at different times on crude protein content in the aftermath cut on November 1st[61].

Time of 1st cutting	Crude protein content of aftermath (%)	
	Leaf	Stem
Jun. 1	24.1	8.3
Jul. 1	23.3	8.5
Aug. 1	22.8	8.6
Sept. 1	26.1	11.4
Oct. 1	25.5	12.3
No cutting until November 1st	16.9	8.2

Table 4. Seasonal changes in crude fat and crude fiber contents (%) of leaves and current year's stems of kudzu-vine.

Component / Researcher / Plant part / Sampling data	Crude fat			Crude fiber		
	KURIYAMA[29]		MIYAMOTO and ŌKAWA*	KURIYAMA[29]		MIYAMOTO and ŌKAWA*
	Leaf	Stem	Leaf	Leaf	Stem	Leaf
Jun. 10	3.3	1.2		21.7	40.1	
Jul. 10	3.8	1.6		25.4	41.1	
29			2.6			23.7
Aug. 10	4.1	1.3		23.5	40.8	
Sept. 2			3.6			25.4
10	3.9	1.7		23.4	43.7	
29			3.4			18.6
Oct. 28			3.3			25.6

* The data were quoted from Soiryo-seisan-gaku, written by KIKUCHI *et al.*[26].

Table 5. Seasonal changes in mineral nutrients of kudzu-vine[35].

Sampling date	Mineral nutrient (%)					
	Total ash	K_2O	Na_2O	CaO	MgO	P_2O_5
Jul. 29	6.50	0.60	0.27	1.99	0.35	0.21
Sept. 2	7.80	0.36	0.21	1.87	0.25	0.26
Sept. 29	8.44	2.81	0.26	2.78	0.20	0.25
Oct. 28	6.32	1.52	0.26	2.02	0.16	0.16

Materials used include leaves, petioles and current year's stems.

the range of 22 to 25% in the leaves and 40 to 44% in the stems during the period from June to September.

Besides the findings mentioned above, the following chemical analyses have been reported :

Table 6. Digestibility of the components of kudzu hay ingested by sheep[22].

Component in kudzu hay		Sheep No. 1		Sheep No. 2	
		Feces ingredient	Digestibility	Feces ingredient	Digestibility
	(%)	(%)	(%)	(%)	(%)
Dry matter	85.2	94.6	56.1	94.0	58.3
Organic matter	77.7	84.2	57.2	84.3	58.2
Crude protein	20.8	8.0	83.3	7.9	85.6
Crude fat	2.6	2.1	70.9	2.0	78.9
NFE	52.1	41.7	46.0	42.4	47.5
Crude fiber	29.3	32.4	46.9	31.9	46.0
Pure protein	16.5	—	—	—	—

Table 7. Percentage of chemical components for feed in leaves of some strains of kudzu-vine.[2].

Strain no.	Locality	Leaf type	Hair on stem	Moisture in leaflet (%)	Crude fat in leaflet (%)	Crude protein in leaflet (%)	Crude fiber in leaflet (%)	Crude protein in petiole (%)
1	Tottori-shi (Tottori pref.)	±	Hairy	12.5	3.8	16.6	19.2	5.8
2	Niihama-shi (Ehime pref.)	−	Hairy	12.7	3.0	17.9	17.2	4.6
3	Tashiro-cho (Kagoshima pref.)	+	Hairless	12.8	2.7	19.1	16.4	6.6
4	ditto	+	Hairless	13.0	3.2	19.9	16.4	6.3
5	Fukui-shi (Fukui pref.)	−	Hairy	13.2	4.9	20.1	14.8	5.1
6	Nishi-no-shima-cho (Shimane pref.)	—	Hairless	12.7	3.9	11.9	18.4	5.5
C.V(%) in 71 strains				3.1	21.3	17.0	9.4	12.0

* Kudzu leaves were classified into three types according to the absence and presence of lobe in the leaves. (−) type: without lobe in three leaflets, (±) type: with and without lobe in lateral and terminal leaflets respectively, (+) type: with lobe in three leaflets.
The localities of strains in Table 4 are shown by solid circles in Fig. 1.

seasonal change of mineral nutrients[35] (**Table 5**) ; carotene, carotenoid and vitamin C contents[17] ; tannin content[11] ; composition and content of amino acids[34] ; nitrogen free extract (NFE) content[14,16,21,59] ; digestible crude protein (DCP) content[14,44,59] ; total digestible nutrients (TDN)[14,44,59] ; starch value (SV)[14] ; digestibility[22,37,41] (**Table 6**) and nutritive ratio[59]. It is considered that differences might exist in the contents of these chemical components among strains of kudzu which grow wild in various parts of Japan[2] (**Table 7**).

Conclusion

Forage crops should be good in the following respects : (1) feeding value, (2) palatability, (3) productivity, especially in leaves, (4) propagation ability, (5) tolerance to trampling pressure from livestock, (6) ability to regrow after defoliation and tolerance to defoliation,

(7) perennial habit and long-term maintenance of their pastures, and (8) adaptability to climates and soils. Kudzu has been recognized to meet most of these conditions[44].

Kudzu can also grow in wastelands where it is impossible for other crops to grow, resulting in an effective use of a limited land space. As kudzu can grow with low fertilizer input, there are no hazards of environmental pollution, which may result from the use of large amounts of chemical fertilizer required by many exotic pasture plants. Kudzu has a wide range of utilization as forage because it is able to provide feed for sheep and rabbits as well as cows and horses. Kudzu is suitable as a pioneer crop on barren soil due to its ability to vigorously propagate and to improve the soil fertility. In Japan, kudzu is used as a way of overcoming the summer growth depression of swards, as it is a summer crop with high drought resistance. Furthermore, in the future, it is thought that kudzu will be able to be utilized in leaf protein, alcohol and biogas industries[27,47,58].

The author only directed his attention to the merits of kudzu from the standpoint of its utilization. However, recently, scientific journals and newspapers[8,45,54,63,64] in the USA have reported that the growth of kudzu around trees and telephone poles has caused serious problems in the southeastern states. Similarly, in Japan a way of eradicating kudzu effectively is needed before growing trees in plantations. Thus, when planting kudzu, the possibility of it becoming a harmful weed should be considered.

If the climbing behavior of kudzu can be regulated, this species could be put into a sod-culture system in fruit growing and used as a cover crop under tree plantation in the tropics. There are said to be some promising chemicals effective for regulating the growth habit of kudzu. As has been indicated by TAKEMATSU[46], these studies to regulate the climbing behavior, including the screening of growth regulators, are of great importance in the practical use of kudzu. Also, in addition to the findings by ADACHI *et al.*[2] indicating that several strains of kudzu exist in Japan, observation by the author suggests the possibility of a dwarf strain existing in Japan. Seed collection of kudzu should be conducted all over Japan for this reason and in orler to identify strains with high foliage and seed production, and high forage quality.

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クズの栽培と利用

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